IAIMS and Health Sciences Education

Support of Health Sciences Education by Integrated Academic Information Management Systems (IAIMS)

Proceedings of a Symposium Sponsored by The National Library of Medicine

March 12, 1986

U.S. DEPARTMENT
OF HEALTH AND
HUMAN SERVICES
Public Health Service
National Institutes of Health

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Contents

Foreword

The National Library of Medicine (NLM) provides grant support to assist in the planning and development of Integrated Academic Information Management Systems (IAIMS), and in the conduct of research related to IAIMS activities. The IAIMS concept is to use computer and communications technologies to bring together a health institution's various information resources into a unified, easily accessible system. The goal is to integrate library systems with the multitude of individual and institutional working information files, such as clinical, administrative, research and educational databases.

In 1980 the NLM supported an Association of American Medical Colleges (AAMC) study of the impact of new information and communication technologies on the roles of health science libraries in a radically changing health care and education environment. The resulting report, "Academic Information in the Academic Health Sciences Center: Roles for the Library in Information Management," called for immediate action on the part of health organizations, professional societies and associations, foundations, industry, and the Federal Government to assist health science centers in adopting state-of-the-art technologies to manage the knowledge base of medicine.*

As one response to the study recommendations, the NLM, in 1983, embarked on a long-range IAIMS prototype development program. The program was initiated through four competitive contract awards for IAIMS strategic planning to the medical centers at Columbia University, Georgetown University, the University of Maryland, and the University of Utah. Subsequently, the NLM incorporated the IAIMS initiative into its extramural programs of grant support, and announced the availability of IAIMS planning and development grants. This action was followed shortly afterwards by another announcement of grants to support research related to IAIMS activities.

The IAIMS concept and the contents of the AAMC report were extensively discussed by the health science community in the year following publication, and were the basis of various programs at major professional association meetings. The NLM was urged to further promote the IAIMS concept, especially to those who might be involved in future IAIMS development or who might be affected by work associated with IAIMS planning and implementation. Accordingly, on October 17, 1984, the NLM sponsored a half-day symposium at its Lister Hill Center Auditorium, and extended invitations to NIH officials, officers of private foundations, representatives of information and communications industries, and members of the academic health sciences and information sciences communities. More than 150 individuals representing 76 institutions in 32 states attended. NLM officers described the IAIMS Program objectives, and the principal investigators from the four medical centers who had received contracts presented their differing approaches and processes used in IAIMS planning. The investigators shared their frank perceptions of the complex issues raised by the IAIMS effort, and commented on the costs and lessons learned. More than 1,500 copies of the published proceedings of the symposium have been distributed.**

As of June 1986, ten IAIMS planning and development grants are active. The awardees are:

- American College of Obstetricians and Gynecologist
- Baylor College of Medicine
- Columbia University
- Georgetown University
- Harvard University
- Johns Hopkins University
- Rhode Island Hospital
- University of Cincinnati
- University of Maryland
- University of Utah

Additional information about the NLM IAIMS Program and copies of the 1984 symposium proceedings can be obtained by contacting the Extramural Programs, National Library of Medicine, Bethesda, Maryland 20894, telephone (301) 496-4621.

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* *Matheson, N.W. and Cooper, J.A.D.: Academic information in the academic health sciences center: roles for the library in information management. Journal of Medical Education 57(10), Oct. 1982, part 2.*

** *Planning for Integrated Academic Information Management Systems: proceedings of a symposium/sponsored by the National Library of Medicine, October 17, 1984. Bethesda, Md.: The Library, 1985.*

Introduction

More than 200 academic health center senior officials, deans, librarians, and hospital directors, representing some 85 institutions, attended the National Library of Medicine's (NLM) second IAIMS Symposium on March 12, 1986. IAIMS—Integrated Academic Information Management Systems—is a grant program sponsored by NLM. The program's primary objectives are to support the planning and development of comprehensive, integrated information networks of computer-based systems and services in academic institutions, and to apply such systems to advancing health science education, research, patient care, and management. The second Symposium, which was presented as a part of NLM's Sesquicentennial Year activities, had as its theme the support of health sciences education by IAIMS.

The IAIMS concept was originally described in a study sponsored by the NLM and developed by the Association of American Medical Colleges: "Academic Information in the Academic Health Sciences Center."* The AAMC report contained in its summary the recommendation that Federal and non-Federal agencies "should support (a) the development of prototype network systems, (b) programs that encourage the rapid integration of information technologies in the learning and practice of the health professions, and (c) programs that attract and retain qualified people in medical information and knowledge-base development in academic centers."

The first part of the recommendation, developing networks, is perhaps the best known aspect of the NLM IAIMS Program in that it has been emphasized in the initial planning phase as a necessary prerequisite to later activities. As summarized below and documented in these proceedings, the March 12th Symposium did include reports from NLM grantees about IAIMS planning and development. Recognizing, however, that institutional planning for the rapid integration of information systems in academic health centers can have an early impact on educational processes and provide a basis for incorporating medical information science research, applications and instruction, the primary focus was on reports of innovations in education and the personnel needed for IAIMS-based research and development.

In his welcoming remarks to the Symposium attenders, Dr. Donald A.B. Lindberg, Director of the NLM, noted that achieving the scientific goals of the next decade, such as mapping the human genome, will require major advances in medical information systems and services. Management decision-making for implementing such information systems is a difficult problem for health science administrators. Students and faculty are in need of computer and information management training. IAIMS activities can greatly assist in the resolution of these issues by developing prototype systems and providing the necessary personnel.

Formal presentations began with reports from four institutions currently receiving NLM support for IAIMS planning. At Johns Hopkins University, Dr. Robert E. Reynolds reported they are developing a new computer-based "nervous system" for the medical center that will link, through the Welsh Library, the existing networks in the Hospital, the School of Medicine, and the School of Public Health.

For Harvard University, Dr. Robert A. Greenes cited the diversity of activity in a highly decentralized organizational structure as a key feature in developing their IAIMS plan to meet existing information needs and new requirements resulting from institutional initiatives in telecommunications, educational reform, new construction, campus-wide information systems planning, and library automation. Dr. G. Anthony Gorry stated that IAIMS planning at the Baylor College of Medicine will emphasize meeting the information needs of the biomedical researcher by developing a knowledge-based system, called the Virtual Notebook System, that will utilize advanced workstations to provide information management capabilities and access. The University of Cincinnati has completed 20 months of IAIMS planning, reported Dr. Nancy M. Lorenzi, resulting in the concept of a patient-centered biomedical information system that includes the core components of a patient-centered community database, value-added knowledge bases, and multiple distributed patient care databases.

The morning session finished with a second series of reports from NLM-sponsored institutions which have completed planning and have begun IAIMS model development and testing. At Columbia University, Dr. Gerry Hendrickson reported that three prototype "mini-IAIMS" applications are underway in education, research, and patient care, as well as the establishment of a new academic center to support education and research in medical information science. Ms. Naomi C. Broering stated that Georgetown University has five objectives: to establish a local area network, to develop an IAIMS test site in the Department of Neurology, to provide learning and teaching opportunities by using computer-based programs, to link administrative offices and systems in the medical center, and to establish an academic information management center within the Library. For the University

of Maryland, the interdisciplinary Hypertension Center was selected as the IAIMS test site, reported Dr. Majorie P. Wilson, and IAIMS-related activities exist throughout the institution, including the creation of a Technology Assisted Learning Center to provide faculty, staff and students opportunities for using and developing microcomputer-based database and educational programs. Dr. Homer R. Warner described the University of Utah IAIMS model testing activity which is being built around the decision-support HELP System that is based on some 400,000 patient records and accessed via 70,000 key words. Utah also has involved the largest Department of Medical Informatics among medical schools, consisting of 10 tenured faculty and 30 graduate students.

The afternoon session of the Symposium, moderated by Dr. Harold M. Schoolman, NLM Deputy Director for Research and Education, was begun with a presentation on changes in education by Dr. August G. Swanson of the Association of American Medical Colleges. Dr. Swanson reported that penetration of medical informatics in educational programs is small, and that the lack of such instruction is the largest area of inadequacy identified by students. Mr. A. Jay Binder, a student at Tulane University School of Medicine and Chairperson of the AMA Medical Student Section, spoke on students' perceptions and behavior with regard to computer use and information needs. Student surveys show that the best way to create an impact on students is to make computers affordable and information science activities useful in the educational process.

The NLM supports five research training programs in medical informatics. The directors of these programs were represented by Dr. Robert A. Greenes, who directs the training program at Harvard University in addition to the IAIMS Program. He stated that much of what IAIMS seeks to provide is still in the research and development stage, and he identified problem areas in patient care, education, research, management and policy, and individual productivity. Personnel needed for such research is in short supply. IAIMS Planning and development will benefit from a close relationship with medical informatics.

The Symposium's formal presentations concluded with reports on health sciences education and medical informatics from representatives of four institutions that are engaged in studying new educational programs. Dr. G. Octo Barnett described the "New Pathway" Educational Program at Harvard Medical School which involves a small group, self-directed problem solving approach to medicine. It features simulations of complex medical situations, and a new approach to computerized knowledge management. At the University of California, San Francisco, Dr. M. Scott Blois, Jr., reported the development of a curriculum in medical informatics for undergraduate medical students which will be included in each year's educational activities. The undergraduate program will focus on the relationships between facts and rules in medicine, and the organization of knowledge. Dr. Lawrence M. Fagan discussed how the SUMEX AIM Project at Stanford University is being decentralized to support medical education, and the kinds of prototype projects that are being developed as well as the problems encountered. The process of education at McMaster University is problem-based, stated Dr. R. Brian Haynes, which requires students to develop information processing skills that can be greatly and readily enhanced by computer technology. McMaster has developed a number of teaching systems based on simulations and expertise, and these are subjected to a thorough evaluation.

The Symposium concluded with an open discussion period during which the attenders had an opportunity to ask questions of all the presenters. In closing the Symposium, Dr. Lindberg noted it was important to recognize a distinction between training and education: the challenge is not to teach students how to use computers, but to provide a foundation in health information science that will enable health professionals to successfully engage in life-long learning by taking advantage of the most modern technology.

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* *Matheson, N.W. and Cooper J.A.D.: Academic information in the academic health sciences center: roles for the library in information management. Journal of Medical Education 57(10), Oct. 1982, part 2.*

Agenda

March 12, 1986

7:30– 8:30	**Registration and Coffee**	
8:30– 8:45	**Welcome and Introduction to the Symposium**	
8:45–10:00	**IAIMS Institution Reports**	
	Johns Hopkins University	Robert E. Reynolds, M.D., Dr.P.H.
	Harvard University	Robert A. Greenes, M.D., Ph.D.
	Baylor College of Medicine	G. Anthony Gorry, Ph.D.
	University of Cincinnati	Nancy M. Lorenzi, Ph.D.
10:00–10:30	**Break**	
10:30–12:00	**IAIMS Institution Reports**	
	Columbia University	Gerry L.F. Hendrickson, Ph.D.
	Georgetown University	Naomi C. Broering, M.L.S., M.A.
	University of Maryland	Marjorie P. Wilson, M.D.
	University of Utah	Homer R. Warner, M.D., Ph.D.
12:00– 1:15	**Lunch Break**	
1:15– 1:45	Association of American Medical Colleges Report	August G. Swanson, M.D.
	Report from Medical Student Section, AMA	A. Jay Binder
1:45– 2:00	Report from NLM Medical Informatics Training Grant Directors	Robert A. Greenes, M.D., Ph.D.
2:00– 3:15	**Reports from Institutions on Medical Education and Informatics**	
	Harvard Medical School-Massachusetts General Hospital	G. Octo Barnett, M.D.
	University of California, San Francisco	Marsden S. Blois, Jr., M.D., Ph.D.
	Stanford University	Lawrence M. Fagan, M.D., Ph.D.
	McMaster University	R. Brian Haynes, M.D., Ph.D.
3:15– 3:30	**Break**	
3:30– 4:30	**Panel Discussion**	All Participants
	Audience Questions	
4:30	**Adjournment**	

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Welcome

Donald A.B. Lindberg, M.D.
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The National Library of Medicine

Art Broering, ladies and gentlemen: it is a pleasure for me to welcome you to the second of the IAIMS symposia. I am certainly the most interested of all of you in what is going to be said today. I will not delay you unduly by a long formal welcome.

I do want to say a little bit about why I'm so interested in this particular meeting by bringing to your attention three counterpoint themes that seem to me to resonate in our meeting. First, there is the undercurrent theme from the medical center front offices—the deans, provosts and chancellors concerned about how many millions of dollars must be spent on telecommunications. What sort of networks to put in? How to be responsible administrators on behalf of their institutions? How to do the right thing, and how to make the decisions that may commit their institutions for some 20 years? I won't belabor that point because I'm afraid that, while it isn't much spoken of, it is much in the minds of university administrators.

The second theme won't be discussed formally during the course of the day, I imagine, but it is pertinent. In recent remarks Don Fredrickson, who is a former Director of NIH and currently President of the Howard Hughes Research Institute, announced a goal for the next decade: to map the entire human genome. We have to pay increasing attention to such a possibility. There is a muttering, even over coffee in this neck of the woods, that quite aside from political "sloganeering," it is entirely possible—here or someplace like this—that the mysteries of oncogenesis may truly be understood in the next ten years.

Well, the problem in a nutshell is that this is not possible without major breakthroughs in information systems and medical informatics of a sort which are as essential as the much to be desired breakthroughs at the laboratory bench and at the clinic. It is not possible to do the molecular biology work without reference to computer data bases which themselves reference the literature and abstract it. The current systems are bursting at the seams at a point at which they are handling only .01 percent of the human genome. We do know six percent of E. coli, but only one hundredth of one percent of the human genome. Don Fredrickson's goal represents a real challenge. We need progress in medical informatics. We need research in this field, and not in an "ivory tower" but in close coupling with those who do molecular biology.

The third theme is to me the reason for the special focus of this particular IAIMS symposium on education. I won't steal their thunder, but I think you'll hear in the afternoon from Gus Swanson and Jay Binder about the displeasure of our graduating medical students with the level of preparation they receive in the use of computers and automated information systems. The third theme, in other words, is education. While that will be more formally focused on in the afternoon, education clearly is the *raison d'etre* for this particular year. It is too simple to say, "Education will solve all of our problems," but those of you who are seriously dealing with the IAIMS programs are also seriously recruiting. I think that you are probably finding that the world is not full of talented, well-informed health science professionals who are cross-trained in informatics. Are you? If so, we could use some help, too.

NLM has never had a program which directly trains medical students or subsidizes their training. By 1976, however, we did have grant-supported training programs in Computers-in-Medicine/Medical Informatics in eleven institutions. These programs had 96 fellows, predoctoral and postdoctoral, under NLM support. "Progress" is marked by the fact that in 1986 we support only 29 trainees in only five institutions. We are marching in the wrong direction and we don't like it at all. Yet, even if we were able to double or triple the size of the training program, the fundamental problem would still rest with the medical centers. The vast preponderance of undergraduate and graduate students will have to learn information management skills through regular curricular mechanisms.

To me the rationale for this meeting is to resolve the three themes and make it come out right. We hope this will help those of you who are making the decisions for your institution to invest your monies wisely, and to make the right decisions for progress during the next 20 years. As I said, I'm eager to hear how both the new wave of the IAIMS schools and the former wave are grappling with this problem. I'm sure that you will have a profitable interchange. I hope each of you will see a model, one that suits the particular needs and strengths of your own institution. I wish you well in the endeavor.

An Integrated Academic Information Management System (IAIMS) at the Johns Hopkins: Plans and Progress

Robert E. Reynolds, M.D.
Associate Dean for Administration
Johns Hopkins University School of Medicine

To set the tone of my remarks I would like to share with you my view from the Deans' Office of the perilous situation confronting academic health centers today.

Over the past four decades medical science and health care services have flourished in America and reached unparalleled heights, in large measure as a result of the enormous financial investment by the American people, both publicly and privately, into research, facilities, health services and health education.

Today, as these investments are already paying handsome and enviable dividends, the external world in which we exist is changing radically. The very circumstances which underpined our growth and success are being questioned — and altered. One only has to observe our research funding diminishing, our student applicant pool decreasing, our malpractice insurance rates and malpractice suits skyrocketing, our own residents and faculty leaving academic medicine to compete with us from their community hospital vantage point (often with better and new equipment, without the problems of our patient mix, location and old facilities). For profit hospitals and physician groups are more fiercely and effectively competing with us for patients, tertiary services and political support.

We in academic health centers are most certainly not blameless. We are accused of growing a bit fat, a little arrogant and nonchalant, and perhaps at times a bit self-serving. These accusations are no longer being disregarded, nor are we taking the faith and support of the American public for granted. Significant changes are underway to bring us back into favored status, and to prevent America from slipping back into the medicine of the late 19th century. If you will recall, *that* era was characterized by an excess of physicians (many poorly educated and ill-trained), by unscrupulous practitioners preying on an unsuspecting public, and by an anti-scientific, anti-intellectual flavor pervading the attitude of America toward her medical scientists and practitioners.

But, *internally* we have work to do, too. And that is why we are here today. We all recognize that our academic health centers have simply stretched themselves beyond the limits of organizational size and complexity. Our internal nervous systems of communication are patently inadequate to their tasks today. Tomorrow's competitive world of scarce resources, streamlined patient care and demands for rapid, flexible and reliable communications for voice, data, and facsimile demands that we radically improve our communication systems and information infrastructure. Recognizing the high stakes involved, one could well call this need a CRISIS.

Those sinologists amongst you may recall that the Chinese word for CRISIS has two components, one signifying DANGER and the other OPPORTUNITY.

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CRISIS = DANGER & OPPORTUNITY

CRISIS causes us to pause, like the cautionary yellow light, and consider the components of the DANGER and the OPPORTUNITY.

To describe what Hopkins is doing to confront this CRISIS, I must describe a little of our history. The Johns Hopkins Hospital was commenced in 1889, the School of Medicine in 1893, the School of Public Health in 1916 and the Welch Library in 1926. These are the traditional elements of Hopkins that have made it world renown.

During the past four years, however, we have undertaken major new thrusts in horizontal and vertical integration of our health care system. We took over the Baltimore City Hospital and renamed it The Francis Scott Key Medical Center. We commenced our own HMO and have enrolled over 18,000 persons. We started a School of Nursing and formed our own for-profit subsidiary corporation called DOME. In the last few months we have acquired two additional community hospitals, the North Charles General Hospital and the Wyman Park Health System.

In addition, we have built and equipped a magnetic resonance facility with four devices, and we are part way through the demolition/reconstruction of a basic research facility. We are deep into the planning phase for (a) a new cancer center, (b) a new ambulatory care center, and (c) a new asthma/immunology center.

All these changes that have happened or are underway are since 1982! They bring together a huge system of four hospitals and supporting facilities on four campuses, with over 1,800 beds, 1,000 full time faculty, 1,100 part time faculty and 1,200 students, housestaff and fellows and a research base over $100,000,000.

These acquisitions represent a quantum leap for Hopkins in facilities, services, educational potential and resources. However, when they are combined with our traditional base and complicated by the stressful changes

in our external world, they heighten our awareness of the CRISIS in our communication system and information infrastructure — our nervous system.

What are the dangers inherent in this CRISIS for Hopkins? They are fragmentation, disorganization, disintegration and failure of our enterprise. In the past we have been permitted the luxury of fragmentation, disorganization and inefficiency, but these potentially fatal genes must be engineered out if we are to survive and prosper.

What is the opportunity presented by our CRISIS? It is to build the NEW academic health center, one that is coordinated, organized, integrated and successful in meeting the outside competition and prospering in its academic and service missions.

What are the NEEDS to turn this CRISIS into an OPPORTUNITY? Like Ancient Rome, they are ROADS, RULES, RIGOR AND RIGHTEOUSNESS. By ROADS I mean the physical components of our new nervous system — the communication links. By RULES I mean the protocols, agreements and standards by which we all use these ROADS. By RIGOR I mean the institutional resolve to make the investments and carry out the actions necessary to assure success of this new nervous system. And by RIGHTEOUSNESS I mean the inner certainty that this step is a SINE QUA NON for the continued viability and vitality of the academic health center.

Today at Hopkins we have made substantial progress in building these new roads and communication links. Our whole East Baltimore campus is now linked together by an ETHERNET system with multiple types of access. We are in the final stages of an RFP for a voice/data/facsimile PBX. We will crosslink all these systems to maximize the communication and networking potential.

TODAY

Hospital-wide Ethernet, and Operational/Clinical Systems

School of Public Health Ethernet and Academic Computer Center

School of Medicine Ethernet, Microcomputer Center and Microwave Facility

Welch Library Computer Systems

Selection Process for New Campus-wide PBX

Cross Linkage of all These Systems

These communication links serve as the backbone of the new nervous system at Hopkins. The GOAL of this new nervous system is to assure an integrated network for information flow, exchange, access, retrieval and management to service and buttress the missions of patient care, education, research and resource management.

TOMORROW

The Plan:

Electronic Workstations for Scholars, Clinicians and Managers

Incorporate Medical Informatics in the Curriculum for Medical and Graduate Students

Stimulate and Support Research and Education in Medical Informatics and Artificial Intelligence

Enhance Faculty and Student Awareness, Knowledge and Skills in Computing and Information Management

Expand and Enhance the Number and Variety of Data Bases and Their Availability

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For TOMORROW, our PLAN has the components seen above and focuses upon (a) electronic workstations for scholars, clinicians and managers linked together through our networks, (b) development and inculcation of medical informatics into our academic environment, and (c) encouraging and promoting computer awareness and usage by our faculty and students. Pursuit of these specific goals demands commitment, dedication of resources and a heavy investment of time and educational effort in working with our faculty, students and administrators. Steps are already underway in several of these items, thanks in part to our IAIMS grant support.

To summarize, I feel we are facing a crisis of communications and information flow in academic health centers combining elements of DANGER and OPPORTUNITY. We at Hopkins have chosen the path of recognizing (and hopefully avoiding) the elements of DANGER while exploiting and maximizing the elements of OPPORTUNITY. It may take a few years to learn how successful we have been and we will return with a full report.

Approaches to Planning In a Prototypical Decentralized Environment: The Harvard IAIMS Project

Robert A. Greenes, M.D., Ph.D.
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Characteristics of the Environment

The Harvard Medical community encompasses the three professional schools: Harvard Medical School (HMS), Harvard School of Dental Medicine (HSDM), and Harvard School of Public Health (HSPH); the Francis A. Countway Library of Medicine; and the fourteen hsopitals and other medical care delivery institutions formally affiliated with HMS. The latter include the Beth Israel Hospital, Brigham and Women's Hospital, Brocton Veteran's Administration Medical Center, Cambridge City Hospital, Children's Hospital, Dana-Farber Cancer Institute, the Harvard Community Health Plan, Massachusetts Eye and Ear Infirmary, Massachusetts General Hospital, Massachusetts Mental Health Center, McLean Hospital, Mount Auburn Hospital, New England Deaconess Hospital, and West Roxbury Veteran's Administration Medical Center. In addition the Harvard Medical community includes a number of other institutions which are not formally affiliated.

Considering all of the above participating institutions and the large number of faculty, staff, residents, and fellows associated with them, HMS and its sister professional schools constitute the largest postdoctoral biomedical training facility in the world. Along with this size, however, comes complexity. The organizational structure is quite decentralized, with each health care delivery institution having its own board of directors and administration. The clinical departments of HMS are composed of committees of the chiefs of service at the various health care delivery institutions. Research facilities often function quite autonomously. The "every tub on its own bottom" philosophy has been a primary organizing principle. Cooperation is generally achieved as a consequence of mutual shared interest, rather than by fiat. The HMS Dean's office focuses on the provision of services required by all participating institutions, the coordination of HMS educational activities, and the facilitation of cooperation among the institutions where required.

In this decentralized environment we are fortunate to have seen a large number of computer activities fluorish, resulting in considerable capability in a wide variety of areas. Multiple medical computing laboratories, several well-established, are active in providing services to their constituencies. Activities span the following areas:

- *Patient care* — ambulatory, hospital information systems, clinical department systems, decision support systems, special clinical computing systems
- *Medical education* — physiologic & clinical simulations, interactive video, medical vocabulary & concept building, knowledge retrieval
- *Medical research* — data base management, data analysis, image processing, mathematical modeling
- *Management & policy* — administrative computing systems, cost-effectiveness analysis, forecasting, modeling, planning
- *Personal & professional productivity* — electronic mail systems, bibliographic search services, bulletin boards, scheduling

As a consequence of this diversity of activity, there are a large number of computer users, particularly in some of the affiliated hospitals. Widespread and rapidly growing use of microcomputers is also occurring at Harvard, as is true elsewhere, with upwards of an estimated 3,000 microcomputers in the medical community. We have also achieved considerable network connectivity through a "grass roots" network development project. A predoctoral and postdoctoral training program in medical informatics, and a predoctoral training program in health decision sciences, at Harvard involve a number of laboratories in which students and faculty are engaged in collaborative projects, and which sponsor a number of medical informatics seminars, lecture series, colloquia, and journal clubs.

The Need for Planning

Despite the above diversity of activity, the various computing capabilities, services, and educational opportunities at Harvard are nonetheless not currently available on a generalized basis throughout the medical community. In addition to wishing to address the challenge of providing these services more generally, Harvard has recently become involved in several other initiatives that have created a demand for more centralized planning, among which are the following:

- *Telecommunications* — Several of the area hospitals and the medical school have each determined the need to provide more cost-effective voice communications, while at the same time handling data needs, and have initiated planning processes for this purpose.
- *Educational reform* — The New Pathway Project in General Medical Education is a major educational initiative at HMS[1]. This Project seeks to reduce the reliance of the physician on memorization and factual recall, and to improve the capability for problem solving and use of information technology to support clinical decision making. This requires development of a set of computer-based tools and communication capabilities that facilitate access of students and faculty throughout the Medical Area to relevant data bases and knowledge.
- *New construction* — Several new buildings and construction projects are underway in the Medical area, including the Bioscience Research Building, the Children's Hospital Medical Center Building, and the General Medical Education Building. Planning efforts have been initiated aimed at determining the most appropriate way to equip these buildings with desired communications and information capabilities.
- *Campus-wide information systems planning* — Harvard University's Office of Information Technology has begun to look at how to most effectively provide telecommunications, equipment, education, and planning services on a University-wide basis.
- *Library automation* — The Countway Library is participating in the Harvard On-Line Library Information System (HOLLIS), being developed to link some 100 faculty libraries at Harvard, for acquisition, and on-line catalog and bibliographic record access.

Principal Objectives of IAIMS at Harvard

The Harvard IAIMS Project process is aimed at providing a central focus upon which the multiple themes identified above can converge, for the purpose of coordinated planning, including the identification of needs, resources, funding requirements, and through which development can be facilitated. The foci of the IAIMS project are in the following areas in particular:

- Identification and facilitation of the development of *new functions* not provided by existing resources, that are desired but not likely to exist without central involvement; this includes building of consensus, helping develop specifications, and aiding in obtaining resources
- Provision of capabilities for *access to new functions by* individuals using their own *established computing resources*
- Facilitation of *access to established functions* by individuals *not* otherwise *served*
- Provision of *interface capabilities among established facilities* for access to functions of mutual interest
- General *service and support activities,* education

The groups of users to be served by this range of activities are the populations that exist in any medical institution currently, to a greater or lesser degree, and consist of (1) those users of existing multi-user computers, (2) those individuals using microcomputers with or without access to a multi-user system, and (3) those individuals currently without access to a computer system. Interconnectivity among these groups and between them and external, non-Harvard computer systems is desired.

An Incremental Approach to Planning

A key aspect of our approach to planning is that it is an incremental one. The incremental approach entails selection of near-term projects that will provide tangible benefit in a reasonable time frame, with modest effort, will satisfy a perceived need, and will help to uncover difficulties and barriers to implementation, which need to be specifically addressed. Successes from the initial project and modifications of the approach based on difficulties encountered will help to ensure the success of subsequent project undertakings. This process of selection of projects, implementation, and refinement of the approach occurs in an iterative fashion. Nonetheless, it occurs in the context of an overall strategic goal, which itself is refined and further developed as experience is gained.

Educational Foci of IAIMS at Harvard

Initial projects to be undertaken by the IAIMS program will focus primarily on educational activities and on services that enhance personal and professional productivity. Emphasis on projects of these types have the following advantages to us:

(1) They tend to cut across traditional institutional boundaries, thus forcing us to address the problem of inter-institutional communication at an early stage. Furthermore, if the services to be provided are perceived as useful, they can serve as an incentive for participation by the institutional computing services in provision of compatible interfaces.

(2) Educational and personal and professional productivity applications are widely recognized as desirable, yet typically not widely available. Thus provision of these capabilities fills a gap that does not compete or duplicate existing services to the extent that other applications might.

(3) The perception of need for these capabilities has been stimulated to a great extent by the New Pathway initiative, not only by participants in this educational experiment, currently involving only about 1/6 of the first-year class and about 80 faculty members, but also by those students and faculty who are not part of the New Pathway, and to whom its capabilities will be less readily available for some time.

Among the applications that we are considering for initial implementation are the following:

- Low cost bibliographic search facilities, using less expensive storage and communications methods than are currently available to our users
- Network management services, for identifying user address and mail routing pathways, and for selective dissemination of current contents, news, meetings, bulletin board communications and other notices, according to user profile descriptions
- Workstation-based knowledge management, knowledge retrieval, and personal filing system capabilities
- Lookup capabilities for determination of standard vocabulary & taxonomy classifications to support the above

Significance of This Project

The approach we are taking at Harvard to IAIMS planning is quite different from that taken at a number of the other institutions participating in this Symposium. While we are coordinating the activity through a central office, our success will depend to a very large extent on cooperation and shared interest by a wide variety of participants. The diversity and lack of central controlling organizational structure of the Harvard institutions prevent a truly ''top-down'' planning activity. Further, one of the strengths of the environment is the wide range of existing capabilities that have sprung up in various laboratories and institutions, or have come about through ''grass roots'' cooperative planning activities.

This provides both a challenge and an opportunity to learn how integrated services can be provided through cooperation without central control. We would submit that this is, in fact, the problem that will be faced by most institutions, even those with very strong top-down control. Unless the purchase of individual computer systems for specific departments and the procurement of microcomputers by individuals is highly regulated by the central administration, every institution faces a plethora of local computing solutions within their walls, some of which will be compatible and some not, some up-to-date and some obsolete. Furthermore, in those institutions with strong medical informatics research and development programs[2], the impact of these efforts on the kinds of services to be provided will be even more difficult to incorporate into a cohesive planning process. Thus, while the diversity and lack of centrality of planning at Harvard may be different in scale from that of many other places, I believe that an approach to planning that recognizes this aspect of the environment, and attempts to deal with it, will have the highest likelihood of success at any institution.

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An IAIMS for Baylor College of Medicine

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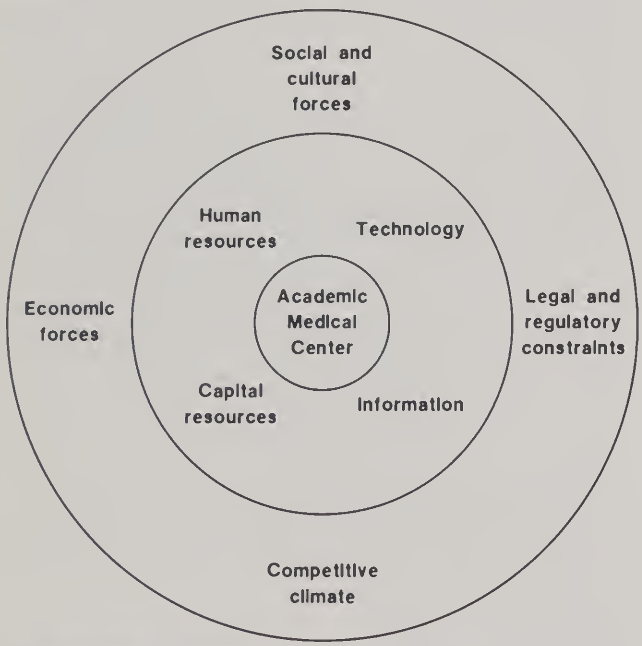
The concept of the IAIMS, admirably described in the article by Matheson and Cooper, is a rich one that provides strong motivation to those academic medical centers that wish to enhance the excellence of their programs of education, research and patient care. The effort required for a single institution to reach the level of information management envisioned in the fully articulated IAIMS concept will be formidable. To be even partially succesful in such an endeavor, an institution must muster an impressive array of technologic and intellectual resources, and it must effect significant organizational changes. The complexity of the IAIMS concept and the unique aspects of each academic medical center means that despite the presence of certain common features, the evolutionary

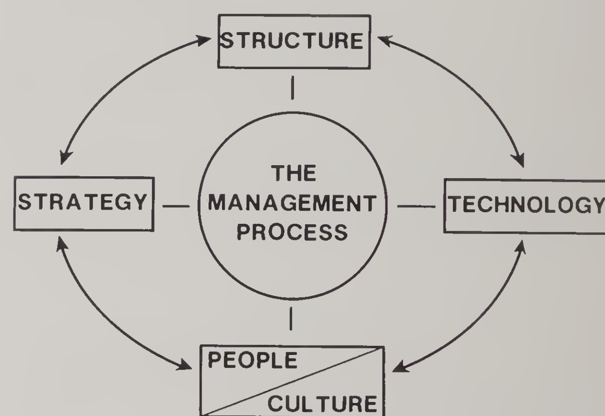


Management Challenge for the Academic Medical Center

paths followed by systems in different institutions may be divergent. This figure describes some of the elements of the management problems faced by academic medical centers today. Furthermore, the elaboration of the IAIMS concept in a particular institution will reflect the degree to which information management technology has already been integrated into the organization. Then, too, problems or opportunities with respect to fiscal or human resources at a particular time may dictate a more or less expansive view of the role of IAIMS in an organization.

Critical Success Factors

As shown in "Organizational Equilibrium" below, managers must try to maintain an equilibrium between the various components of the academic health science center. This balancing process is not easy to achieve or maintain. The many worthy problems or projects usually exceed the resources available. To make these tough choices, critical success factors (CSFs) for the organization must be identified.



Organizational Equilibrium

Therefore, whatever form the IAIMS takes in a particular institution, its success will depend on more than just mastery of technical aspects of the system. Success will be directly related to how well the IAIMS contributes to the achievement of the organization's other objectives. Since resources are likely to be limited, the IAIMS must then be designed and implemented around those CSFs most likely to benefit from the application of computer-based technology.

So IAIMS planning must be an integral part of the institution's strategic planning efforts. The institution's strategic planning efforts must take into account the value of computer-based, information technologies when applied to the institution's unique set of problems and opportunities. No matter the technical sophistication or merit of an implementation, an IAIMS that does not support the strategic goals of an institution and which cannot be demonstrated to support those goals is doomed to be perceived as a failure. It is crucial that the persons responsible for setting the strategic goals of an institution be involved in the IAIMS effort and, in turn, become knowledgeable about the value of IAIMS and its supporting technologies.

IAIMS Planning at Baylor College of Medicine

IAIMS planning at Baylor College of Medicine has been integrated into an ongoing strategic planning effort. This planning effort was started to guide the integration of information technology into the corporate functions of the College. The scope of this strategic planning effort was expanded somewhat when we added the formal IAIMS planning efforts to this process. For this reason, we do not perceive a clear deliniation between our corporate information systems and the IAIMS. The two functions have a symbiotic relationship — success in one contributes to success in the other.

A clear lesson to be drawn from our experience is that IAIMS planning and implementation is likely to be a lengthy effort. It takes time to put together a team, develop the necessary skills and coordinate the IAIMS effort with other parallel activities. It also takes time to change the perceptions about information systems on the part of some major contributors — the institution's decision makers and faculty.

BCM is a major research institution, ranking fifth nationally among medical schools in the size of its research faculty and eighth in its research funding. Since research productivity is one of the most important determinants of Baylor's success, we proposed to design and implement an IAIMS with primary emphasis on meeting the information management needs of the biomedical researcher. The College has labored to develop a research environment that fosters this productivity. We believe that information technology, properly applied, can play a substantial role in further enhancing that research environment.

A Model for the BCM IAIMS

There have been many attempts to develop computer-based technology to address the set of problems faced by researchers. Some of these attempts have been quite narrow scholarly systems that attempt to address a specific research area (e.g., a system for molecular biology research or for the analysis of clinical research data). Other systems have taken a broader approach, though usually by packaging together a number of scholarly systems. Both approaches have provided considerable benefit to the research community. Some are widely used and have stimulated interaction beyond what was anticipated.

We believe that ideas underlying these systems can be extended. These systems are aimed largely at data management. However, a researcher is also engaged in the management of knowledge. Effective biomedical researchers are effective because they are good knowledge managers. Knowledge management skills complement all the other creative skills of a biomedical researcher.

While data management problems are well-understood, knowledge management problems are somewhat more diffuse. There is, however, a body of experience with comparable types of problems in the area of management science — decision support systems (DSS).

One clear lesson from DSS research is that it is very difficult to develop a knowledge management system without a model of the function to be supported. For our IAIMS work, we need a model of the knowledge management activities of the biomedical researcher. For this, we have chosen to modify the model of a manager that has been previously developed by Mintzberg. This model of a manager, while not perfectly matched to the biomedical researcher, offers us the chance to start our model specification from a higher level.

Why this model? Most biomedical research today is performed not by individuals but by groups of 4 to 10 people. Small groups usually consist of one professional, one or more full-time support staff (i.e., research technicians), and possibly a student or professional-in-training. Larger groups will include more persons but generally also include more professionals. Large or small, each group has a single person responsible for the direction of the group. For the sake of simplicity, we will call that person the laboratory director or LD.

In the rest of this section, we will discuss in very abbreviated form the Mintzberg model of a manager and its relevance to the biomedical researchers knowledge management needs.

Mintzberg defined a total of ten roles that a manager fulfills. He grouped these into three classes or types of roles. These are.

- Interpersonal
  - o Figurehead
  - o Leader
  - o Liasion
- Informational
  - o Monitor
  - o Disseminator
  - o Spokesman
- Decisional
  - o Entrepreneur
  - o Disturbance handler
  - o Resource allocator
  - o Negotiator

It is usually the case that the LD is both manager and scientific leader, although, in groups with several professionals, scientific leadership is often a shared responsibility. According to this definition, all LDs are managers in the traditional (i.e., Mintzberg) sense. LDs have a parallel set of roles when they function as research leaders. There is a certain correspondence between this set of roles and those described by Mintzberg. We will use the Mintzberg Model as a starting point to build our own model of LD function.

One additional feature must be added to the model which we use as our starting point. There is considerable interaction between groups, and this interaction is complex and variable. It could not be deduced from examining an organizational chart. This interaction is an important part of the scientific process, and it must be managed as any other resource. Therefore, our model includes information about the interactive needs of the biomedical researcher.

Description of BCM IAIMS

To meet the managerial needs of the biomedical researcher, we have decided to implement a knowledge-based system (KBS) that integrates the functions of workstations, database servers and other specialized computers into a single system.

We have selected as a paradigm for our system the *researchers' notebook*. The advantages of this paradigm are:

- The concept of the role and use of a research notebook as an information repository is widely accepted by researchers and their staff.
- The notebook is widely accepted by biomedical faculty and staff as the central information repository for locally-produced information in the research setting.
- The notebook is adaptable to many types of research (e.g., laboratory research as well as clinical research).
- The notebook does not constrain the types of data collected or its organization. Many types of data are written, taped, pasted, etc., into a notebook. Data are organized in different ways by different users.
- Notebooks are accepted by the courts and regulatory agencies as documentation of research activities (i.e., their value is accepted outside of the research setting).

We call the KBS we are developing the Virtual Notebook System (VNS). The VNS will extend and enrich the information organization and storage capabilities of the traditional researcher's notebook while helping to support the managerial roles of the biomedical researcher. Additionally, through the VNS, the researcher will be able to reach out to the growing number of computer-based information collections and to access needed knowledge in a consistent way. One feature of the VNS that will facilitate integration of information for the researcher is the incorporation of a very large semantic network of biomedical terms derived from the Medical Subject Heading (MeSH) vocabulary developed by the National Library of Medicine.

There are several examples of the use of the notebook (or similar ideas) as a paradigm for KBS. Among these are the CSL Notebook from Xerox's Palo Alto Research Centers (PARC), the NoteCard System (also developed at PARC and now marketed by Xerox), and the Engineer's Notebook under development by Tektronix.

While all of these projects have contributed useful ideas to our paradigm, none of them is directly applicable to our environment. None of them was designed for the special needs of the biomedical researcher. None of them can take advantage of a controlled vocabulary (and candidate semantic network) like MeSH. None offers assistance in the managerial roles of the biomedical researcher nor fosters an environment which facilitates interaction.

Some features of the VNS are summarized below.

- The user will be presented, via appropriate windowing software, with what looks like a computerized notebook.
- The ultimate home for the VNS software will be a powerful workstation. A database server and other computer-based resource will be available to the workstation via the communications network.
- The information in the VNS will be available via more than one external view (i.e., logical model) of the data.
- The VNS will make it possible to assemble virtual notebooks. For example, a lab supervisor's notebook could automatically include the results produced by the laboratory staff. However, lab technicians might only have access to their data. Either would be able to alter the organization of their notebook at any time (e.g., from chronological order to project order or worker order).
- The smallest data structure of the notebook will be called an object. Objects will consist of data in different forms (e.g., tables of data, sketches, images, output from instruments or computer programs, etc.)

- Objects may be organized into larger units. We do not know the best way to do this. Objects might be associated into pages, experiments, or some other unit of work. This association into units of work might be permanent or virtual. Objects might include:
  1. Text/numbers
  2. Graphs/Diagrams/Sketches
  3. Images
  4. Instrument/Application Program Output
  5. Templates/Protocols — from user libraries
  6. Database Queries
- Each object (or unit assembled from an object) will be automatically identified with a time, date, originator and project. Additional indexing information (necessary to permit alternate organizational schemes) may also be assigned by the user. Indexing terms will be derived from a superset of MeSH to be developed as part of this project. The types of indexes used might include, in addition to the ones cited above, 1) objects used; 2) status — complete, incomplete, etc.; and 3) types of objects.
- Changes will be monitored and/or controlled. Certain types of information might be volatile (e.g. a literature search) while other types (e.g., results from an experimental apparatus) might be permanent.
- Some objects or work units will start life blank but can be altered through the imposition of one of a limited number of templates or skeletons (e.g., table, text, graph, etc.). Predefined templates will be available (e.g., to get data into an analysis package). Building blocks will be provided for user-designed templates.
- Objects or work units will accept data from tools accessible to the system (e.g., graphs from graphics package). Data need not be limited to text or character graphs but might include images or graphic images.
- One type of object will permit the user to invoke foreign applications (i.e., those not developed by us) as well as IAIMS applications and trap the output for inclusion in the VNS. For example, academic or management information from the Baylor corporate information systems would be accessible through a VNS object.
- Sharing of information, both within and between groups, will be an important function of this system. Sharing will be made as easy and transparent as possible. The system will also make it possible to easily acquire information from other sources.
- Text and other information could be highlighted and used to index and link objects/work units to other objects, etc. The use of terms would be limited to MeSH terms and a controlled list of research-specific terms (e.g., experiment, results, working vs. archived, open vs. completed, etc.) to be developed as part of the VNS project.
- Objects or work units could be routinely routed to others (collaborators or research supervisors), sent on demand, or held secure (default).
- The user can make a snapshot of any VNS object for transmission to others by electronic means or by copying to paper via a laser printer.
- Objects/work units may be assembled into special type of object called a manuscript. This object will also include text, graphs, etc. The accessibility of information and the ease of reorganization should significantly affect the authoring process.

Summary

Our initial work on the development of an IAIMS for Baylor College of Medicine has been illuminating. It has underscored the need to link IAIMS planning to important and specific organizational objectives. Our efforts have also benefitted from our adoption of a strong conceptual framework — a model of the managerial tasks involved in biomedical research. Finally, we have been forcefully reminded that the road to a full IAIMS realization in a given institution will be long and fraught with technical and organizational difficulties. For those institutions that desire to realize the full potential of advanced information technology, this road must be followed. We, at Baylor, are committed to the IAIMS path and are looking forward to meeting the challenges before us.

Integrating Information: The University of Cincinnati Medical Center Approach

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In our 20 months of planning at the University of Cincinnati, we have recognized that IAIMS is intangible: IAIMS is a *concept* which, at first, can only be visualized, talked about, thought about, and planned for. We have also seen that it is not just an evolving concept but also a continuous *process* and, in all likelihood, it will remain a continuous process for several more years. It is a process which involves political and educational issues equally. This paper briefly reviews the political, conceptual, and educational processes which support IAIMS at the University of Cincinnati Medical Center.

As we move toward an established and accepted structure the conceptual process, relative to the other processes, was sketched-out fairly quickly. At our Medical Center, as with most, the political process has been approached slowly and carefully. By contrast, the educational process can be implemented and produce tangible results at the inception of the planning effort. While all three processes unfold at different rates, they come together in planning, and form the foundation of the IAIMS leadership direction for our Medical Center.

IAIMS — the political process.

There are a multitude of "turf" issues raised by the IAIMS planning process. Some issues include the roles and responsibilities of the library, the information professional, and the computing center. Issues surrounding the respective roles of the various medical disciplines, the hospital, and the total medical center organization are addressed within the planning process as well. Once the roles of these groups are sorted and clarified, each will have a direct impact on the policies implemented to support IAIMS. The policies must address issues of information: confidentiality, information control, autonomy, access, and so forth.

And indeed, it is *information* that is *the* issue (though some find it easier to understand IAIMS as a computer network). Our issue is clearly not computing; our issue is *information* — ownership and control of it, access to it, and the autonomy of its users. The IAIMS process has assigned a special value to information. The process brings information into sharp relief, placing the planning team amidst a marketplace of buyers, sellers and, it is hoped, sharers.

IAIMS — the conceptual process.

From the very beginning, our IAIMS leadership developed a process and a mechanism which effectively treats the concept of integrated information as an evolving system. We suspected that the core of the matter conceptually was the effect of the reorganization and re-valuation of the information, or content. Our approach was to link the *content* and its various methods of organization to *users* through nearly transparent *technologies.* Thus, to direct attention to each of these three key areas, our organizing task forces range from Information Management [Policy] to Attitudinal/Behavioral and from Education to Technology. In support of these four basic task forces we added a Finance and Evaluation Task Force. (Figure 1)

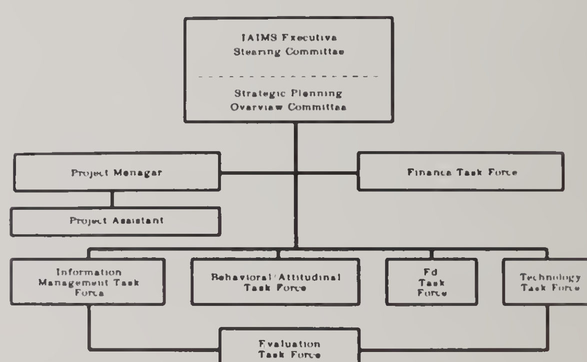

Figure I. The University of Cincinnati, Medical Center IAIMS Planning Process Organizational Structure

Of particular interest also to the educational process is the IAIMS Attitudinal and Behavioral Task Force. Two of the recommendations they made were 1) to make sure that we did not focus only on computer literacy and 2) to develop an understanding and a response to the way that actual users use information in their everyday work and practices.

The IAIMS Education Task Force is a Medical Center-wide group whose task has been defined as the promotion and integration of *information literacy* for faculty, students and staff at our Medical Center. They believe that users must be literate in the language of a system in order to consume its products. Importantly, their charge is not simply to develop computer literacy programs, (which is a problem now being solved in conjunction with the Computing Center) but to support information literacy as the intelligent and effective use of information by users in their everyday work and practice. Users must

understand the unique content of an information system, the particular means by which it is organized and the way information can be strategically applied.

On February 23, 1986, I spoke before approximately 150 participants at the Association of University Professors of Ophthalmology Conference. Since this group represents ophthalmology department leaders, we thought it would be an excellent opportunity to introduce them to the IAIMS concept. Their responses were a microcosm of those we face daily. There were instant positive responses and at the same time there were many who felt threatened. The threat was demonstrated by statements such as "the administration does not know how our departments and practices should be run;" "all of this depends upon who is in charge of the system;" "the physicians could lose control of the information that belongs to their patients or to them." In response, I explained that a basic principle of our IAIMS is that it is a system by which information modifies management, not management modifying information.

The University of Cincinnati IAIMS Overview Strategic Planning Committee established our conceptual direction as follows:

> *The UCMC IAIMS is a patient-centered biomedical information system which integrates clinical, academic, and management information for improved patient care, education, research, and quality assurance. Users' information needs are met through multiple gateways and access levels. The core components of the UCMC IAIMS are a patient-centered community database, interacting with multiple distributed patient care databases, and value-added knowledge bases, each generated from the patient-centered database, relevant biomedical literature, and everyday health care practices.*

The brief objectives of the planning process have been to:

1) Develop a management/leadership framework, policy-driven goals, and long-term financial strategies.
2) Assess current and planned technologies; perform projections.
3) Assess environment, attitudes and potential of Medical Center user population.
4) Evaluate three projects designated as IAIMS prototypes.
   - office automation
   - clinical laboratory medicine computer system
5) Evaluate the planning process.
6) Develop a plan, model and timetable for IAIMS implementation.

At the heart of the UCMC IAIMS conceptual framework is the patient-centered database, (Figure 2) a centralized, community repository of individual patient information reflecting the medical record and critical demographic information. Represented as satellites surrounding the patient-centered database are integrated, interactive patient care information systems which satisfy the data-handling and information requirements at the level of the discipline, department, or specific mission.

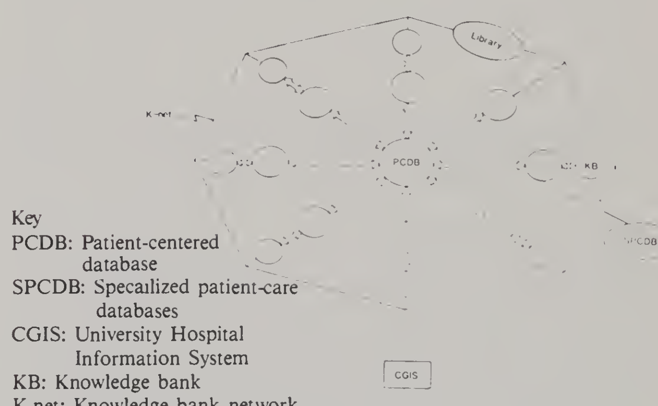

Figure 2. IAIMS Conceptual Framework

Figure 2 is meant to be envisioned three-dimensionally above Figure 3: Medical Center information support systems, for example, the Clinical Laboratory Medicine computer system and the Drug and Poison Information Center are integrated within the conceptual framework as well.

Part of our conceptualization process includes design of a knowledge network (K-net). This is the structure that links together all databases and information systems of the Medical Center to national and international systems. It is a *navigational system* that allows users to move from one place to another without the need to understand technologies in any depth. It is also a system that makes suggestions for effective search strategies, so while in the process of using the system, users become increasingly more knowledgeable about how to find their way around it.

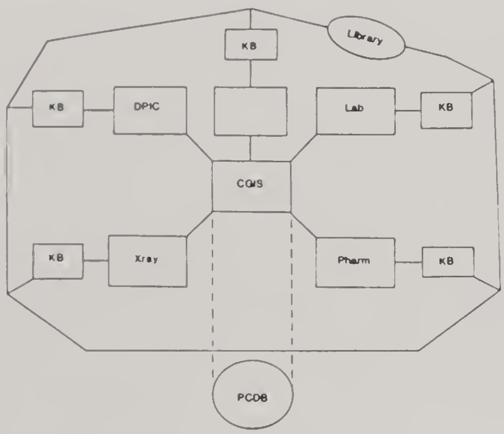

Figure 3. Medical Center Clinical Support Systems Which Support CGIS (University Hospital's Information System) and the Patient Centered Database (PCDB)

IAIMS — the education process.

Physicians are not quite certain what IAIMS means because, initially, there are no buttons, bells and whistles or models to demonstrate. To increase their understanding, we created a fictitious patient — Mary Smith.[1] Mary Smith wakes in the middle of the night seriously ill. Her husband informs their physician at his home. The physician, in turn, sends her to University Hospital. The scenario that we have used time and time again follows all of the information and decision support systems that are necessary for the effective diagnosis, treatment, care, research and educational needs of the patient, her family, and all health care providers who come in contact with Mary Smith. By using this scenario and depicting the care of a patient as a focus of our IAIMS, we successfully convey the concepts and directions of our planning process.

On hearing this scenario, participants begin to think about IAIMS applications that are particularly useful and unique to them; it prompts thoughts about original contributions they could make to the development of the system.

Another facet of the education process comes from the organization Medical Center Information and Communications, (MCIC), which provides the administrative structure for IAIMS. Several MCIC units have responsibility for the development of technology-based tools in support of the education process for all segments of the Medical Center. Current products range from a quality filtered, user-friendly database for students, as well as an information management center, a microcomputer demonstration lab, and plans for interactive videodisc support throughout the Medical Center and the University.

Medical Center Information and Communications (MCIC) which was created in 1983 to support the information and communication needs of patient care, research, education and community service combines several Medical Center units — medical illustration and photography, educational television, the libraries and museum services, extension services/marketing, a news bureau, and other support departments — into an integrated organization (Figure 4). The Medical Center Information and Communications organization offers a variety of services for creating, retrieving, processing, and delivering health care information and communications.

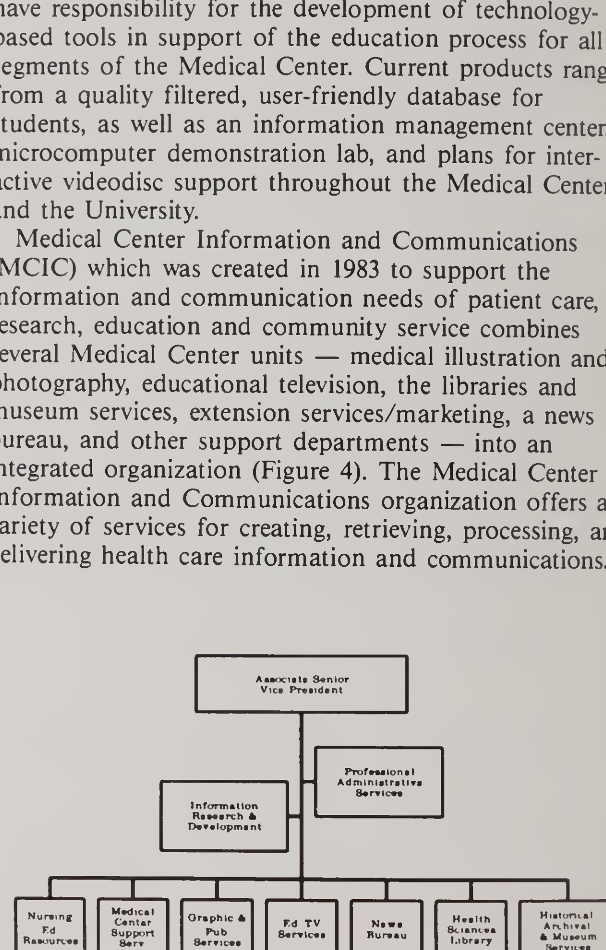

Figure 4. The Organizational Structure for the Medical Center Information and Communications System

[1]Lorenzi, Ph.D., N.M., "Making a Dream Come True: Strategies for Medical School Libraries," *Bulletin of the Medical Library Association*, October 1983. Volume 71, No. 4, p. 410-414.

The Department of Information Research and Development was conceptualized as our area to develop and research concepts regarding integrated information. Thus, it is within this department that the IAIMS process both for the Medical Center Information and Communications unit and for the total Medical Center officially is housed. This department has staff who are a blend of process and content (physicians, researchers, information systems, library, computer, and communications specialists).

In summary, the knowledge network is a concept which provides the structure within the IAIMS, that logically and physically links together all databases and information systems of the Medical Center. It is a concrete network and set of services which, along with other MCIC educational services, serves to support and create an information literate medical center. It is a system which allows users to move from one information source to another without realizing that a source's origin may be local or national. In effect, K-net opens to the users the universe of biomedical information.

The IAIMS process legitimizes a medical center taking the time to effectively deal with the multitude of information resources that are currently available and will be available in the near future. In an important and exciting way, the IAIMS process has provided us all with new ways of thinking.

However, *the IAIMS Process raises as many questions as it answers.* Some of the questions raised in our planning process include: What does it actually mean to effectively use information in one's work?; What is the meaning of increased access to information? And for example, what happens in a medical center when an resident or fourth year medical student has access to as much information or more than the senior physician serving as the attending?; Is IAIMS the great leveler in bringing students, residents, nurses and physicians (important not to refer just to docs!) to the same level as it pertains to access to information? How can we link academic types of databases and information smoothly into a process that focuses on patient care? How will the integrated information concept change the way health care is practiced? When our Mary Smith wakes up in the middle of the night, will we be there and will we be ready to handle the information needs as it pertains to this patient?

The Role of IAIMS in Stimulating Educational Change at the Columbia-Presbyterian Medical Center

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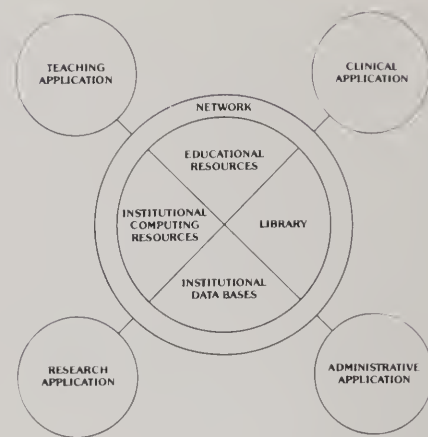
In this report, we present preliminary observations on the role of IAIMS planning and implementation in stimulating educational change. This topic may be of interest for at least two reasons. In the first place, we found that the IAIMS process per se acts as a stimulant of change. Second, it appears to us that the linkage of the institutional IAIMS to education is likely to serve as a powerful lever in broadening the IAIMS user community. Yet the creation of such linkages must be undertaken circumspectly, as the use of computers in medical education is still an emerging field, one in need of extensive research and development efforts to provide a broad range of programs and to define their utility.

IAIMS at the Columbia-Presbyterian Medical Center

The Columbia University Health Sciences Division and the Presbyterian Hospital in the City of New York are, through their permanent alliance agreement of 1921, partners in operating the Columbia-Presbyterian Medical Center (CPMC) in the upper west side of New York City. There, several health sciences schools offer degree and certificate programs; a 1291-bed voluntary teaching hospital and a state psychiatric facility provide patient-care; and biomedical research is conducted in numerous fields. The Hospital's professional staff all hold appointments on Health Sciences faculties. The CPMC's size, age, research and educational focus, decentralization, and administrative structure are among the attributes that distinguish it from many other academic medical centers.

In developing both its strategic plan for IAIMS implementation and its pilot project, Columbia drew upon a distinction that has become central in the University's planning for information management: between core resources which undergird the use of computers in patient care, research, education, and administration, and user-specific applications. Core resources, or infrastructure (Figure 1), include the library, certain computing resources (central computers, general-purpose software, the network), institutional databases (hospital records, as well as budget, financial, and personnel data), and certain educational resources. Infrastructure resources are, generally speaking, available to the CPMC community at large. Although provided and managed centrally, they are funded in various ways. For example, library services are both provided and supported centrally; whereas others, such as certain computer installations and networks, are provided centrally but supported by user charges. Still other core services are provided centrally and supported by a combination of user charges and central subsidies. In all cases, however, the central administration is responsible for developing the financial arrangements for core services and for setting policy concerning their use.



Schematic Representation of Relationship Between IAIMS Infrastructure and Applications.

The focus of the Columbia IAIMS effort is on the infrastructure, since its creation and management are most efficiently defined, organized, and conducted as institutional responsibilities. Accordingly, the principal investigator for IAIMS-related research and model development is also the institutional officer with ultimate responsibility on the health sciences Campus for providing, financing, and setting policy for services and resources that are part of the infrastructure—i.e., the Vice President for Health Sciences.

Columbia's strategic plan for IAIMS development describes a sequence of steps for strengthening and enhancing the central infrastructure while encouraging user-specific applications in a variety of settings. The model development program now being conducted under NLM auspices sets into place "pieces" of the IAIMS envisioned in the strategic plan. By positioning these pieces, we are making inroads in all areas of the strategic plan, albeit limited in some instances. Thus, we are using the model development program to launch the comprehensive effort. Columbia University funds are being used to:

- Extend the University's information policy; create and fill the position of Director of Information Services;
- Extend the IAIMS physical infrastructure and establish a user room where consultative, training, and educational services are provided.

Funds from the National Library of Medicine are being used to:

- Enhance the scope of library services and increase access to them;
- Develop an educational service designed to provide new computer users with advice and technical assistance;
- Test IAIMS operational, administrative, and financial concepts in three "mini-IAIMS" (a hospital clinic, a laboratory and teaching service, and an interdisciplinary clinical research project) where academic and clinical information must routinely and continually be integrated;
- Evaluate the effectiveness of these core services in meeting user needs.

In designing the model development activities we provided for blending support from NLM funds with institutional and extramural funds to give us experience with the complex funding patterns that will govern full-scale IAIMS support.

Educational Change

Early in the planning process it became clear that a paramount need was to create education and training programs that would equip faculty, students, and staff to use contemporary information technology. A major factor contributing to this need is the Presbyterian Hospital's modernization program, which now is being carried out. By 1989 a new tertiary care hospital, an offsite community hospital, and renovated facilities will be in use. At the same time, physicians' offices will be established in various neighborhood and other remote locations. The use of automated databases and networks is integral to the modernization program, and indeed the Hospital plans to install computer terminals at every bedside and in other treatment settings, and to store, retrieve, and process patient records by electronic means. At present, relatively few clinicians or other faculty members make use of electronically stored records, and many lack the pertinent technical knowledge, skills, and habits; but by 1989, they will be expected to have mastered them. As an institution Columbia's Health Sciences Division is in the early portion of the computer applications learning curve; to keep pace with the Medical Center's growth, its personnel will have to "climb" the curve within only a few years to attain at least a modest level of competence.

This expectation defined one of the major tasks for IAIMS development during this period, namely, to educate a community of naive users. Much of what needs to be done falls in the category of "training" rather than "education" and would enable most members of the community to engage in at least rudimentary use of the new tools at their disposal. Certain members, however, undoubtedly need to achieve higher and more sophisticated levels of competence. In addition, students will need to be prepared to practice medicine and engage in research in an era in which both will increasingly rely on computing.

Because the needs for IAIMS-related educational programs were so large, amorphous, and multifaceted, they were difficult to address fully in the ongoing IAIMS model development effort. We therefore chose to make a limited response during that phase, namely, educational services for new computer users, recognizing that the mismatch between the needs and the efforts mounted was great. At the same time, we elected to pursue these issues through other channels.

Several opportunities to address some educational needs presented themselves virtually at the onset of the model development effort. One was "Project Aurora," Columbia's mechanism for allocating a $6.5 million equipment gift from IBM among its faculties and schools. In developing a rationale for the Health Sciences' application for a share of this gift, IAIMS staff had extensive occasion to educate and counsel faculty members from many departments. A second opportunity was inherent in the great interest of the College of Physicians and Surgeons' curriculum committee in introducing computers into medical education. The committee unanimously resolved that an elective two-semester course in medical informatics be offered beginning in September 1986, and recommended to the Vice President for Health Sciences that he establish an academic center to support education and to begin research in medical information science.

The faculty's interest extends beyond the course on medical informatics. A small but increasing number of them are eager to use computers in their courses to assist them in imparting new content or in presenting traditional subjects in new ways. The expectations of faculty members regarding computers vary, as do plans for their use in courses, but second-year course directors are recognizing that their course material and teaching formats lend themselves well to computer-based interactive case and review programs. Faculty in the School of Dental and Oral Surgery are planning for automation of patient records and scheduling in the clinic and for students to learn automated patient management. Faculty in the School of Public Health look to expanded student use of computers, particularly in their epidemiology and biostatistics courses.

Lack of technical support for faculty members is the main impediment to significant activity. Generally, faculty do not have the time or the expertise to develop computerized course material on their own. We are, therefore, in the process of refining plans for establishing an educational resource comprising staff with requisite expertise, software tools, and equipment of which second-year medical school course directors, and subsequently, other faculty, can avail themselves.

Thus, a variety of solutions is taking shape in response to the different and varied levels of need. These developments reflect a marked change in attitudes about computers in education. As recently as five years ago the P&S curriculum committee saw little need to concern itself with information management. As recently as last year a goal of IAIMS planners was to stimulate such interest. Now our aim is to keep interest within the bounds of the support available and within the bounds of realism.

Role of IAIMS in Stimulating Changes

It is commonplace that educational change usually results from multiple pressures, and that accordingly it is difficult to attribute causality with precision. Despite this we believe that the IAIMS process has been a key factor in promoting change. The IAIMS project has put into place the infrastructure necessary to support educational use of computers. It has also catalyzed plans for the creation of a curriculum to address computing applications in the Health Sciences.

The principal effect of the first months of the IAIMS project at Columbia was to stimulate discussion throughout the administration and faculties concerning information management needs on the campus. A variety of needs and scenerios emerged, both formally in the report of a user needs committee and informally in an environment characterized by increased attention to information management issues.

Many participants in these early efforts focused on both the educational needs and the infrastructural resource needs perceived as the prerequisites for success in developing or implementing applications that served more specific administrative, educational, clinical, or research efforts. The need to develop methods and programs to educate both system developers and applications users evolved into the curriculum on medical informatics to be offered next year and a commitment to build a users' room to support curricular efforts. The need to build an infrastructure led to funding applications to a variety of sources. Support from the National Library of Medicine has been the linchpin of the IAIMS effort. Beyond this, the most successful funding application to date has been the one submitted under the aegis of Project Aurora. This application not only resulted in the award of 100 workstations to the Health Sciences campus but also directly influenced the emphasis proposed in the development of a formal curriculum.

Because of the prior IAIMS awards, there existed an organizational structure to help develop a campus-wide response to Project Aurora. The same individuals who participated in IAIMS user needs committee activities managed the development of the Project Aurora application. These individuals convened the faculty to request applications that would fit into an integrated institutional application. The Aurora Committee, as it became known, established a tone and defined the guidelines for the application process. These guidelines, or selection criteria, included (among others) the application's congruence with our institutional strategic plan and the willingness of the investigator to share all results with others.

A review of the resulting applications disclosed that both the depth of interest on the campus and the technical sophistication of many of the applicants were greater than expected, and that applications could easily be classified into several foci or cores. In particular, many applications addressed image management issues; some, clinical database needs; others, laboratory device interconnection or the development of expert systems. The Aurora Committee and the curriculum committee recognized that these core interests corresponded to the main topics to be considered in the formation of a curriculum in medical informatics and gave evidence of the intensity of the demand for its presentation. This successful application for increased infrastructure

resources was the last component required for the curriculum committee to determine that initiation of formal curricular efforts had become appropriate.

Thus, educational change culminating in the emergence of a new curriculum resulted from efforts initiated in response to the institutional IAIMS planning award. In stepwise fashion, the initial IAIMS contract caused the organization of individuals with computing skills and interests; in turn, this organization led to a coherent statement of needs; the statement of needs crystallized the demand for resources; the application for resources further structured the institutional prioritization of needs; and the award of adequate resources convinced curricular planner of the need for a formal course sequence.

We surmise that the process of educational change triggered by IAIMS will be cyclical. A formal course sequence will serve as the nidus for continuing an association among investigators with information management skills. This continuing association will result in sustained pressure to further define the statement of user needs, and in consequence, the drive to acquire resources to meet such needs will be fueled, leading to the demand for new curricula to enable widespread effective utilization of the new resources. A similar dynamic may be operative in other institutions.

In addition, the IAIMS project has stimulated change at the CPMC in another area. IAIMS resources (specifically, a Digital Equipment Corporation VAX and the user support staff) have enabled the development of an outpatient clinic automation project in one of the practice groups. This project has, in turn, intensified and extended formal planning by the Presbyterian Hospital for a hospital-wide clinical information system and has led to additional effort to clarify and resolve policy issues underlying the successful implementation and management of such a network. In particular, the issues of controlling access to clinical data, assuring the compatibility of devices and data within the Hospital as well as between Hospital and University, and the organizational issues concerning the planning, implementation, and management of such a system have all been refined in the context of planning the system for the outpatient clinic.

Although the projects discussed might have been undertaken eventually in the absence of a coordinated institution-wide approach to information management, the ongoing IAIMS effort has contributed substantially, by catalyzing various activities and by assuring that all are congruent with the Health Sciences strategic plan for automated information management.

Thus, the IAIMS project has been the center of a "cascade" of efforts to develop educational programs and clinical information systems. IAIMS activities have served as the nidus for the crystallization of events which may well influence the direction of the CPMC for decades to come.

IAIMS at Georgetown University: From Strategies to Action

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In 1983, Dr. Donald A.B. Lindberg commented on the "almost complete absence of formal educational programs in medical informatics/medical information science in the curriculum for American medical students." He further indicated that despite increasing research on computers in medicine, the general curriculum pattern continued in a "traditional way isolated from modern computer advances" (1). That same year, Time Magazine announced the computer as the Machine of the Year.

Impact of Computers in Medical Education

Since 1983, computers have entered the world of medical education with a force more powerful than had been felt for the previous fifteen years. Elements and evidence of change are local and national. We are witnessing a trend that profoundly affects our faculty and students. The great impact of computers occurring in medical education today can be attributed to not one, but several environmental factors. Recently on the national scene, forceful statements recognizing the crucial role of computer sciences were made by the four major health associations: the American Association of Medical Colleges in the report on General Professional Education of Physicians (GPEP) (2), the National Board of Medical Examiners' announcement to implement computer-based testing in Part III of the national examinations (3), the Association of Academic Health Centers (AAHC) report by Piemme and Ball on "Executive Management of Computer Resources in the Academic Health Center" (4) and, unveiled about a year ago, the American Medical Association's release of national online access to AMA-GTE NET, medical information databases (5).

Although a few medical schools offer grant supported programs in medical information sciences, not until Harvard University's "New Pathway" curriculum has there been such a powerful institutional commitment to prepare medical students to use these new tools (6). With growing frequency, special medical and basic sciences disciplines are revamping teaching styles to de-emphasize memorization and to use computers as memory extenders.

The National Library of Medicine's (NLM) support for IAIMS planning certainly has served as a vital "change agent" at nine institutions. From the inquiries received at Georgetown, it is apparent that other academic medical centers are taking steps to plan a similar course of action.

Nowhere is the national acceptance of computers in education more apparent than in the emergence of the "electronic library" in medical centers and hospitals. The integrated library system approach, the replacement of traditional card catalogs with online catalogs, and the development of inhouse bibliographic search systems such as the miniMEDLINE SYSTEM (7) at Georgetown and "Paperchase" (8) at Beth Israel Hospital have introduced physicians and health sciences students to automated information access. At Georgetown alone, over 2,500 students and approximately 2,000 faculty annually use the online system during each library visit. Not only have several academic medical center libraries implemented miniMEDLINE, with its collection oriented in-house database of journal references and abstracts, but recently, other institutions have been developing larger scale systems. The commercial world has also responded by offering end-user bibliographic search systems to practitioners, researchers and faculty.

Concurrent with these top-down forces is the bottom-up complement of acceptance and use of personal computers by faculty and students. The exposure to computers through libraries is so monumental that many schools are now incorporating training in bibliographic information access in the students' basic "computer literacy" repertoire. At Georgetown, through the IAIMS program, the Library, the Hospital, and the three Schools (Dentistry, Medicine and Nursing) are making even more tools available for faculty use with students. The recent faculty awakening about computers strengthened by what IAIMS and the Library offers, is serving as a driving force for emerging curriculum changes.

Information sciences are definitely infiltrating courses offered at Georgetown by each of the three schools. Georgetown educational programs, traditionally strong in basic sciences and clinical practice, are integrating information access skills and knowledge of computer sciences in existing courses. For the first time, the institution has assumed responsibility for providing students with educational experiences in information methods. Much of this can be credited to the opportunities provided through IAIMS and the Library's close relationship to the teaching programs of the Schools.

IAIMS Plan

Georgetown is emphasizing education as it moves IAIMS implementation strategies into action. The Medical Center has two major IAIMS goals: the first, to improve academic information management and the transfer of biomedical information by developing an IAIMS. This

goal includes objectives in four primary areas: Education, Research, Patient Care and Management Information. The second goal, to establish an IAIMS prototype, a center of excellence, to serve as a national resource for other academic health science centers and other health related organizations, and to engage in research and demonstrations on the use of advanced technologies in the health field. Georgetown will participate in Information Exchange, Medical Informatics Projects, Conferences on IAIMS and Consortial Activities (9).

The IAIMS plan is intentionally flexible, establishing a general course of action for a ten year period. Implementation will take place in three phases:

Pilot Phase	1-3 years
Interim Phase	3-5 years
Long Range Phase	5-10 years

The Pilot Phase

For the initial pilot phase Georgetown recently received three grants that provide seed support. One of the grants provides equipment for general IAIMS purposes. The other two grants from the NLM are for a three year period. The Model IAIMS establishes pilot programs in different areas of the Medical Center, while the other grant has a research emphasis focusing on the Library and the Vincent T. Lombardi Cancer Center.

Generally, the projects include special applications software programs for unique educational use by the three schools, core support services through IAIMS for the entire Medical Center and planned ultimately are external networking services.

From a systems approach, the projects fall into three categories:

a. Technical Projects — linking heterogenous systems and developing interfaces.

b. Software Development — new databases emphasizing user-friendly systems with the relational database approach, advanced formats and use of medical informatics products.

c. Hardware Systems — designing an intelligent workstation and using state-of-the-art technologies.

Model Development Project

The model IAIMS pilot project has five objectives.

1. The first, to establish a Local Area Network (LAN) which will link the pilot sites to the Hospital Information System (HIS) and the Library Information System (LIS). Connectivity to existing shared databases is being stressed. The sites to be linked are the Department of Neurology, our model experiment; the Cancer Center, our research site; and the Administrative Offices of the Deans of the three Schools, the Hospital, Library, and the Chancellor's Office. IAIMS will begin small with 50 terminal ports in year 1, expand to 250 ports in year 2, and to almost 400 in year 3. It is expected that demand for access will increase, requiring about 4,000 ports in the "Full IAIMS Phase."

2. The second objective centers in the Department of Neurology. An intradepartmental "cluster" of terminals will be networked for department use, and through the LAN, will also provide external access to the HIS and LIS. By using a database management system, the Neurology faculty will be able to develop a patient record database. Additionally, students and residents will be exposed to the databases being developed for the department's strong teaching components. There are eighteen neurology residents and all the medical students rotate through the department.

3. The third objective, to provide enhanced learning and teaching opportunities for health professions education through the use of computer-based programs for clinical problem solving, includes implementing "model" educational systems. The Medical School is exploring problem-solving systems; the Nursing School is working with clinical education software packages; and the Dental School is emphasizing dental literature through an expanded miniMEDLINE database.

The Medical School proposes to review several medical expert systems to help in clinical diagnosis. The two possible systems are: RECONSIDER, developed and generously provided by Dr. Marsden Blois from the University of California at San Francisco (10), and MEDICOMP, a commercial system loaned by a Virginia software firm (11). Ultimately it is planned to select an expert system that students can use to develop or sharpen decision making skills.

The Medical School's long range plan includes a series of steps to:

- modify the curriculum and extend existing computer learning to accommodate an increasingly sophisticated study body.
- continue to encourage faculty to develop clinical simulation models for the curriculum changes.

- require a beginning level of computer literacy for incoming classes and, in the interim, provide courses for those students not yet capable of using computers.
- continue instructional classes in use of Personal Computers through the Medical Library.
- begin use and evaluation of the Georgetown developed PC software package, Personal Information Management for Medical Students (PIMMS), for data entry of student notes and references.
- use the Library Information System and miniMEDLINE, knowledge systems and informational databases to supplement classroom learning.
- sponsor Continuing Medical Education courses on computers for practicing physicians.

The School of Nursing will be developing a clinical case simulation program for teaching nursing techniques using the Nursing Education Module Authoring System (NEMAS). The Nursing School has already begun to implement its long range plan by starting a program in computers in the Nursing curriculum to integrate computer technology in the School's courses and by implementing IAIMS sponsored projects. The activities include:

- an educational model entitled "Concepts in the Curriculum Model."
- a basic course at the graduate and undergraduate level on computer technology.
- integration of computers in the Graduate Program through classes in four Nursing Administration Courses.
- continuing education conferences and institutes on use of computer technology in Nursing. (A five-day institute is scheduled in June, 1986.)
- research projects to advance software for Nursing. Projects already under development include a Nursing component to PIMMS, called PIMNS, and a Nursing Nomenclature Database.
- expansion of the School's existing computer laboratory for faculty.

The Dental School has commenced work on expanding titles in the miniMEDLINE SYSTEM, the Georgetown self-service bibliographic component based on NLM's Medline file. Remote access will be provided from a workstation in the Dental Clinic. While the Dental School's long range plan addresses future curriculum changes, its initial steps are the total automation of the Dental Clinic, where incidentally, students are exposed to computer-based patient management.

4. The fourth objective is a means of linking offices in the five units of the Medical Center through the network and providing office automation computing tools for better information management such as transmitting messages through electronic mail, bulletin boards and calendars.

5. The fifth objective establishes an academic information management center, a training and laboratory environment, within the Library for faculty and student experimentation on current and future IAIMS projects. This information center will provide the training needed for the pilot project and all future IAIMS activities indicated in the implementation plan.

Users at all levels need basic education in information access skills and they will need instruction on use of the IAIMS network. The Library already has in place a small computer facility which will be expanded to include additional software, hardware, communication and personnel resources. The outcome of the Center's educational services include providing scholars workstations and classes for both faculty and students, consulting services, instruction on access to the IAIMS network and a directory of databases. More long range is the opportunity to conduct research projects and to encourage faculty to develop software by possibly lending PCs.

IAIMS Related Research Project

To put a major educational program in place, institutions need to provide basic support resources and tools. Georgetown is addressing this by not only acquiring computers, but more importantly, by extending the health sciences databases that represent the shared databases to be accessed by users.

Generally, there are four types of health databases that relate to the world's knowledge of medicine and if you add management databases, there are five. Highlighted in Figure 1 are the key components of these databases.

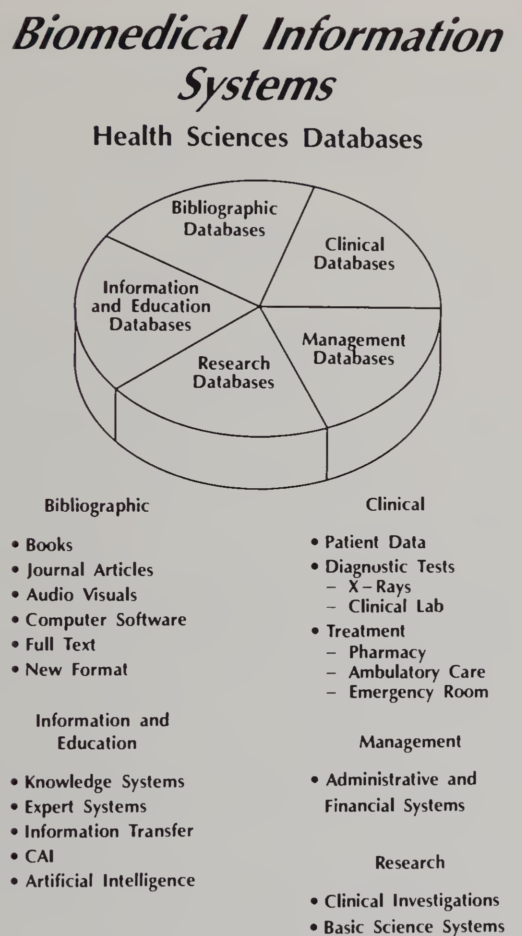

Figure 1. A Macro View of Health Sciences Databases.

The Georgetown research project begins with the Library, since it is a primary source of recorded knowledge through its bibliographic databases. Physicians and researchers depend on accessing the literature to determine if information is available for education, patient care or research purposes. When there is a void, it often leads to new research which in turn adds literature to bibliographic systems, increasing the world's biomedical knowledge base. The other databases represent unrecorded knowledge which is dynamic, usually not in the public domain, and often available only to the owner of the database.

This IAIMS research project examines the usefulness of interfacing bibliographic and information databases by focusing on the Library and a special area of the Medical Center, the Lombardi Cancer Center. The Library databases will consist of two bibliographic systems, miniMEDLINE and a version of Cancer Literature (12); and two information databases, Physicians Data Query (PDQ) (13) and the MicroMedex Drug Information System consisting of Drugdex, Poisindex and Emergindex (14). In addition to designing easy-to-use features, the databases will be interfaced so users can conduct multiple database searching without re-keying search terms. The basis for the medical vocabulary is the NLM MeSH subject headings, but automatic mapping of terms is incorporated in the data dictionary. The staff of five oncology divisions of the Cancer Center will be given training to access these systems and data will be gathered on user behavior and the level of integration that is useful.

As IAIMS is implemented, Georgetown hopes to study the dependency and interrelationship of health databases. Using today's technology it is possible to integrate and interface these databases to give users easy access to readily available information from a variety of sources.

A Look to the Future

Georgetown's strategy for flow of information is to maintain a distributed system approach at the Medical Center. Each unit will maintain and develop its systems and databases, but access and links to shared databases will be provided through the IAIMS network. The IAIMS plan and projects include each of the Medical Center units.

The LAN and the core services available through the computer donation will be used to establish a number of special IAIMS services. The computer location of the information or databases will be transparent to the IAIMS user. The type of information Georgetown intends to provide through IAIMS includes: (See Figure 2)

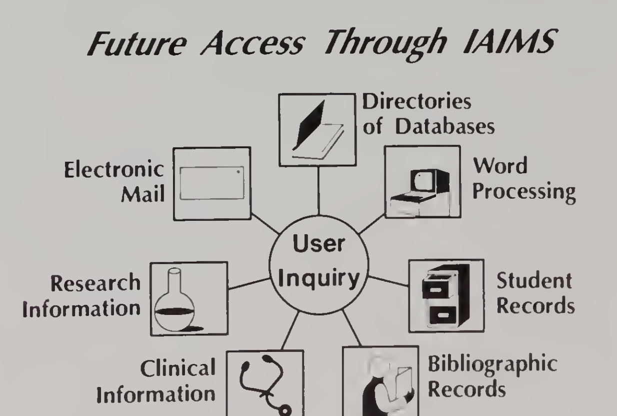

Figure 2. Databases to be Accessible Through the IAIMS Network.

- a directory of databases providing information to the user about the system contents and who to contact for further information.
- access to numerous clinical, educational and research databases available through IAIMS.
- electronic mail, bulletin boards and office automation tools.

Because all the units of the Medical Center have been included in the planning, there is great enthusiasm and as a result numerous future projects covering many additional departments are planned. As an example of these projects, Georgetown is pursuing a scholar's workstation with external/internal networking capabilities. This workstation concept can be used to provide the affiliated hospitals with access to some of Georgetown's databases discussed in this paper. For community physicians participating in Georgetown's teaching programs, the medical center intends to provide similar workstation capabilities.

There are more ideas than projects the Medical Center can afford to fund and there is internal pressure to generate funding for these additional programs. The ten year IAIMS program is an immense undertaking of great importance. Georgetown is beginning to achieve progress through a phased approach. Success is also dependent on continued development of products from medical informatics laboratories. These products are vital to the Schools' future educational programs and to the medical library in its role as IAIMS facilitator and disseminator of information.

The intent of this paper is to provide a few insights into Georgetown's IAIMS, but especially, to share some ideas on how other institutions can launch similar projects. As other medical centers progress, it is hoped that together we can pool our efforts to improve health sciences education for the year 2000.

Acknowledgements

In 1983, the IAIMS program at the Georgetown University Medical Center was launched by Matthew F. McNulty, Jr., Sc.D., Chancellor of the Medical Center when he appointed a committee to pursue a planning program. Thanks to his visionary approach, strong support and commitment, the IAIMS strategic plan and the grant proposals resulted in awards from the NLM and AT&T in 1985. We wish to also recognize and thank the entire IAIMS team of approximately 60 individuals, too many to name here, who have generously contributed long hours to our effort. Lastly, our deepest gratitude to Helen Bagdoyan who provides useful suggestions and Julie M. Ross who prepared the manuscript.

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Status Report: IAIMS at UMAB, 1986

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The Institutional Imperative

If information resources at the institutional level are to be allocated effectively, decision makers must have the right answers to the many questions about the acquisition of hardware and software, systems architecture, and the appropriate organizational structure and locus for managerial planning and control of information systems to serve the multiple tasks of education, research, and patient care. They must undertake *strategic planning* aimed at the most effective linkages of the full variety of information sources of an academic health center to support all prospective users—the student, the teacher, the clinician, the researcher, and the administrator. Key relations among databases must be shaped by user needs and concerns for such characteristics as modularity, expandability, flexibility, and compatibility.

The *institutional imperative,* then, is to manage the core resources as an information utility to improve the speed and quality of the decisions being made in clinical settings, to stimulate and support increases in the speed of the research cycle, and to enhance the self-learning skills of students, while supporting the optimal utilization of limited resources that can be dedicated to information management (6).

What Must be Done to Address the Concerns

The outcome envisioned to meet this imperative is an integrated academic information management system, or IAIMS. Such a system (or systems) requires clear needs assessment and definition of systems purpose, structure, principles and rules, user commitment, resource support, and the attention of effective leadership. The cost of achieving such a system is enormous in terms of time, effort and dollars, but we believe it is worth it in the long run. IAIMS must integrate diverse data needs and overcome inhibiting attitudes and perceptions. IAIMS must take into account priorities, standards and training, and the politics, awareness, interest levels, and feedback of the users. The NLM initiative wisely empowered institutions to undertake strategic planning as a first step in the development of an integrated academic information management system(s).

Some General Principles

IAIMS has a well articulated conceptual framework. The academic medical center is a knowledge-based, information-intensive service organization. Its products are educated students, new understanding and knowledge of human biology and pathophysiology, and medical care to populations who need or desire it from this particular type of institution. Information is a principal component of each of these. Thus, the configuration of information systems has a profound impact on all these functions (7).

The use of the term *integration* in the context of IAIMS is a simple one. The dictionary definition is useful here—"a combination and coordination of separate and diverse elements or units into a more complete or harmonious whole." The objective is to make the tremendous behind-the-scenes complexity of the information and data sources relatively transparent to the user, providing simplified access to diverse internal and external data bases from a single workstation and easing communication with colleagues, students, and others inside and outside the institution. Another objective is to make access available to the *average* user, not solely to the sophisticated computer user, and to place the user in direct contact with the necessary and available information and data sources. The integrated system which is envisioned stresses applications development by end users without programmers whenever possible. The concept is a user-oriented (extremely user friendly or user seductive) information utility in *direct* support of students, faculty, and staff. Obviously, such an increased role for the average end user necessitates a full array of user support—particularly consultation and training by the staff of the centralized computer facilities and the health sciences library.

The networked, distributed system with its user-friendly decision-support software (DSS) will enable professionals in the academic setting to organize data, extract information, develop ideas, and evaluate actions. Advanced telecommunications technology, including a campus-wide network and local area networks, will be used to enhance communication so that information and ideas can be more easily and effectively shared among professionals. Information processing will be distributed and integrated across micro, mini, and mainframe devices with emphasis on the desk top computer as the end user's window into the system.

The Conceptual Framework

IAIMS is directed toward large systems change at the institutional level and targets the institutional *environment* as a whole. The changes proposed by IAIMS at this beginning stage develop a coordinated structure into which more sophisticated developments in medical informatics can be inserted as they are developed and are available for general application—whether these developments relate to education, research, or patient care. At Maryland, we have evolved from an IAIMS strategic plan to now making decisions and taking action in the context of an IAIMS philosophy.

The IAIMS concept is not simply the acquisition of a micro-processor for every desk, but derives from the idea that whichever area is involved—education, research, patient care services, or administration—information and the flow of information must be put into the context of a system which the average user can access easily and directly. As Simon points out, a central problem in our post-industrial, service-oriented society is how to organize to make decisions; that is, to *process information.* "The anatomy of an organization viewed as a decision-making and information-processing system may look very different from the anatomy of the same organization viewed as a collection of people" (5). In the Galbraith model of an organization, the structure that holds the tasks together and thus creates an organization involves rules, procedures and protocols, individual job and task specifications, geographical and spatial boundaries and *communications networks* (2). As Hunt says: "Action (or tasks) finds a stimulus and a description in *communication* (3). Even if no written or oral communication occurs, there is, in fact, continuous communication among coordinated members because of their actions. . .communications will influence action . . . action is related to communication through decision making."

Thus, the concept of an "information processing model of the organization" emerges—a progression from merely recognizing the anatomical structure of the organization to understanding its basic physiology. The obvious conclusion is that institutional executives/leaders must make the development of productive, useful, cost-effective information systems a high priority. Information per se and its attendant processing is an institutional resource deserving of thoughtful, knowledgeable management, not only in support of managerial analysis and decision making, but also in support of and as essential to effective education, research, and patient care. Information is a critical institutional resource and must be managed as carefully and as competently as space, dollars, and personnel (9).

Strategic Planning

As advanced by the National Library of Medicine, the IAIMS initiative has three phases: strategic planning, model development, and implementation.

IAIMS strategic planning requires the institution to develop a blueprint or map of where it wants to go and how it intends to get there. In so doing, IAIMS *targets the institutional environment,* primarily the internal environment, and it targets it from a variety of directions. Structurally and organizationally, IAIMS and the strategic planning it entails have pervasive institutional implications. In addressing the physical needs, namely, systems architecture, and both hardware and software that are needed, IAIMS affects the technical configurations within the institution. It also targets the environment culturally. It defines the attitudinal and behavioral changes that must come about among faculty, students, clinicians, and administrators and promotes the establishment of a strong consensual base among faculty and staff about the use of computers and communications technology.

Relationships will change as individuals and organizational units are linked or networked electronically. The work environment will be transformed as new tools for information handling and decision making are made available. IAIMS helps the institution to identify and to plan what changes should be made.

The Importance of Human Factors

Human factors ultimately decide the success of information systems technology. Therefore, the method for carrying out a strategic planning effort such as IAIMS must be oriented toward important human factors. It is essential to identify the different users of the technology and their specific needs and to develop a consensus around the desired outcomes of the planning effort, a commitment to achieving that future and a comfort with the possibilities of a new information lifestyle and adaptation to it. Broad ownership of the planning process and the outcomes of that process is critical and an essential component of IAIMS (9).

The development of enhanced technological capabilities and the increasingly accessible databases enable IAIMS institutions to develop prototypical systems. Clinically, this will involve the application of expert systems/clinical decision systems and computer simulations which can also be integrated into the health sciences curricula. Educationally, this will mean developing prototypical educational systems designed to enhance the information management and clinical decision skills of health professionals, including appropriate support for evaluating the performance of students and faculty in their use of information for diagnostic and therapeutic purposes. In

concert with the National Library of Medicine, the various IAIMS sites can fulfill their role as prototypes by supporting the continued development and refinement of information systems for their undergraduate, graduate, and continuing medical education programs and professional school curricula and by sharing this experience and expertise broadly.

The IAIMS sites, as visible as they are, can facilitate the development of academic units in medical informatics as essential components of health science educational institutions. IAIMS sites can contribute to the training programs required to strengthen medical librarianship and mount appropriate new training programs for the development of professionals in the organization, management, and use of health science information systems. Various research initiatives are also part of IAIMS activities. For example, a promising new approach has shown that by combining the latest commercially available products in symbolic processing and multiprocessor scientific computing workstations, what we are calling Adaptive Medicine Information Systems (AMIS), an environment can be created which makes computers adapt to the user's problems and terminology in a manner that lets him take advantage of his medical specialized intuition (1).

We are fortunate to have had an outstanding Mathematics, Physical Science and Engineering Division from our College Park campus join forces with us at the Baltimore campus on this project. We anticipate some of their graduate students will want to come to the Baltimore campus to work on these advanced medical applications. In a different research area another group of investigators studying innovation and technology diffusion will identify a group of opinion leaders who will assume the role of gatekeepers to facilitate the branching or spread throughout our campus of the models developed in our IAIMS pilot project (4).

In its initial proposal, UMAB presented the concept of the "vertical slice" as a manageable first implementation step. The University of Maryland Hypertension Center, an interdisciplinary "center without walls" was selected as the pilot site, or vertical slice. This center involves people and resources that cut across a spectrum of departments and schools. The products and methodologies developed in the prototype will have direct applicability to the campus as a whole and will be transportable to other sites in a phased branching process.

The center has clinical ties which over a two-and-a-half-year period, have the potential for building a research database in excess of 100,000 subjects. Rapid electronic information transfer, large scale databases, and the coupling of micro, mini, and mainframe computers is essential. A network that enables rapid communication between clinicians, researchers, students, and administrators in diverse locations is being developed. Center participants require ready access to bibliographic databases available through the Health Sciences Library as well as a new bibliographic database specific to the literature on hypertension.

Hypertension sites in the School of Pharmacy and in the Department of Medicine, Epidemiology, Pathology and Physiology of the School of Medicine are involved in the prototype IAIMS implementation. Responsibilities have been assigned to these units, with the core library and computer facilities providing technical expertise and user support services.

Pilot site objectives have been defined as follows (8):

- To utilize the campus-distributed network and office automation software to connect the various discrete and widely separated units involved in the Hypertension Center
- To establish local area networks linking the Hypertension Center microcomputers, enabling data sharing and other functions
- To improve capabilities for information transfer between systems by providing gateways between the microcomputer environment of the local area networks and the campus mainframes
- To develop an enhanced multiprocessing workstation which will address the requirements for virtually simultaneous end user access to the extensive array of microbased decision support software
- To implement an end user environment with multi-access/multidisciplinary databases and powerful information handling and decision support tools

To achieve these objectives, pilot and core facility personnel are involved in the selection of software to be shared on the local area networks and linked to the campus-wide fourth generation language, relational database management system. Under a train-the-trainer scheme, end user education is coordinated by specially designated personnel within the pilot site and the core facilities.

Prototype database development will improve access to and processing of hypertension-related information as well as working models for the majority of database needs which will be encountered campus wide. These include applications in administration, education, clinical services, and research. They involve the development of new databases from both manual systems and existing computerized databases. Existing databases are being analyzed to determine methods of redefining or restructuring to enhance the potential for interlinkage. Procedures are being developed to facilitate access to information within and across databases.

A strong evaluative component runs through all these tasks, with the process, product, and impact of all prototype activities continually monitored. This evaluation will ensure that mid-course corrections are made during the pilot. In addition, the analysis will ensure that the successes of the pilot can indeed be transported, both to other sites on the UMAB campus and to other academic health centers.

Since the participants in this symposium today are interested in IAIMS support of health sciences education per se, I shall focus on this element of our activities in my concluding remarks, although I must point out that every aspect of our IAIMS effort contributes significantly to improving *the environment* in which health sciences education takes place. Decisions from the new telecommunications system selection to the installation of the new hospital information system and linking it with the patient record in a new ambulatory care building are made with an eye to educational and research objectives.

Since the inception of IAIMS, we have added several IBM PC's and printers for student use in our Learning Resources Center, which is a satellite of our Health Sciences Library. We are in the process of translating 50 internal PLATO programs with the use of the TenCORE authoring system and language for use on these PC's. The "Cardiovascular Systems and Dynamics" computer programs are being used in the physiology course and the students are utilizing computer-assisted learning software in microbiology. We are seeking computer-assisted instructional programs that have been developed for the basic sciences, as the majority of our development thus far has been in the clinical simulation area. The IAIMS philosophy which is influencing our thinking and decisions at all levels has provided an umbrella to shelter and pull together activities which have begun in a variety of ways such as our FILUM and Fulcrum projects.

Faculty in our Department of Neurology in collaboration with colleagues in the Department of Computer Science have been studying the application of artificial intelligence (AI) in Neurology for over five years, and this work has resulted in a dozen or more expert systems which have all been developed on a large mainframe. These investigators are now exploring the feasibility of developing a library of neurological expert systems that can be run on IBM XT workstations.

Although CAI has the highest priority in the utilization protocol, computer utilization by students is not restricted to CAI. As is common in most higher education institutions today, we have made standard software available to students, including word processing, spreadsheet, database, and utility programs, all of which receive constant use.

The Technology Assisted Learning Center

A tangible outcome of the initial UMAB IAIMS effort has been the establishment of a Technology Assisted Learning Center (TAL). The physical space has been renovated and twelve microcomputers put in place in this new facility. Existing software and courseware is being collected and catalogued. Workshops emphasizing hands-on skill development are being offered for students and faculty at various levels of computer literacy. The Executive Committee of the School of Medicine charged the Department of Epidemiology and Preventive Medicine with the responsibility of defining appropriate course work and other learning experiences to assure the competence of medical students and residents in technology assisted learning and other computer applications. Actually, about one-third of our entering students now have their own personal computers, so it is not an issue of introducing them to computers but incorporating these technological applications in their life-long learning.

The TAL Center is the core of the micro-based initiative for testing a variety of end-user driven database system and educational programs introducing 4th generation database and query language concepts to the faculty, staff, and students. In addition to using these computers to deliver existing educational programs, the TAL Center is the primary area for the development of new and innovative micro-based medical and epidemiological educational software. Due to the overwhelming response to the TAL Center activities, we must develop a second TAL classroom.

We could all list many, many activities relating to medical education which touch a variety of problems and, at Maryland, most of the other health professions as well. For example, our dental school has developed learning objectives for all of its courses and, with the use of the computer, is able to match the results of its examinations with those objectives and measure achievement

of the objectives and the effectiveness of the teaching programs.

But, in my view, we have not gotten at the root problem. Harnessing technology to support ineffective instructional strategies will not do. Simply using electronic technology to transfer more information while reducing the time needed for the transfer does not deal with the real issue. The technology must be applied to support the personal knowledge base which will allow students to develop as active learners, effective problem solvers, and information seekers.

We really pay little attention to the fact that styles and strategies of learning influence the approach of the student to learning except when faced with serious remedial challenges for students who come from disadvantaged educational backgrounds. In addition to the inherent and acquired differences that students bring with them to medical school, we are faced with the added diversity of dealing with graduate and undergraduate students and with the study of the basic sciences and clinical sciences, all of which are different. There is need for computer-integrated instruction, the computer in support of the entire learning process to support instruction, to provide instruction, to manage instruction and to manage the personal knowledge base. Medical educators must discover how technology can be used to provide active learning situations in the basic science years and to provide support for the decision-maker in the clinical years and beyond. Our goal for the students is a vital, dynamic interaction with the aid of this technology throughout the undergraduate curriculum to be then carried out naturally as part of the graduates' life-long learning strategy (6, p. 48-56).

Our Education Functional Advisory Group set forth eleven process issues and recommendations as part of the initial strategic planning for IAIMS, including literacy; evaluation; updating; organization and administration; expert advice; ongoing hardware and software decisions; faculty time, rewards and roles; curriculum impact and decisions; standardization of software, hardware and language; who pays?; and security and confidentiality. We see a need and an opportunity for the NLM to assist us with this agenda, and I suspect many other medical schools have a similar agenda.

We feel a great need to network with other schools. Our research and managerial needs and applications are well in hand in many respects, and still we find it useful to exchange information with other institutions, whether it be about telecommunications systems vendors or planning methodology. However, the educational area calls for more revolutionary change. The problems to be solved go to the heart of what we know of learning theory, and we must have a mechanism which can go beyond the limitations of one faculty to bring about the changes needed in our approaches to medical education. We all recognize the seminal educational reform efforts of Case Western Reserve, McMaster, Southern Illinois, and now Harvard spanning some thirty years, and no doubt half this audience sat in a curriculum committee meeting within the month where the hours devoted to one subject or another was the principal subject of discussion! Why do we not come to grips with the real educational problems more effectively?

I look forward to the program this afternoon to learn how these medical education and informatics activities have pervaded the institutional culture and the extent to which we may profit from these experiences and translate and/or transport these programs to other institutional settings. This is clearly an arena in which the National Library of Medicine and the Association of American Medical Colleges can provide the stimulus of convener and facilitator, and a generalized support system to materially advance the depth and breadth of our engagement with the fundamental educational issues as well as accelerate the speed by which the solutions are uncovered and shared. I have no doubt that industry and the foundations would also find major elements of interest in this process. IAIMS has caught the attention of the academic medical center leadership in a way no NLM program has before with the possible exception of the NLM library construction grant program of the late Sixties. It seems to me there is an uncommon opportunity here.

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Development of a Prototype IAIMS at the University of Utah

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IAIMS at the University of Utah is now in the prototype development phase. A major activity this past year has been the completion of our integrated library system for the Eccles Health Sciences Library. We have now installed a system developed by OCLC which is running on a Data General machine and provides, among other services, online access to the complete catalog of library holdings. This will provide important new services to users in all four colleges (Medicine, Nursing, Health, and Pharmacy) on the medical campus. In addition, we have embarked on the development and implementation of some other innovative components of a prototype integrated information management system for the medical center at the University of Utah. The focus of this effort is to structure medical information in the form of models that will be useful in solving problems in a clinical setting.

Information needed to solve a medical problem can be obtained from three sources:

1. a patient database,
2. the medical literature, and
3. an expert in the subject.

Existing computer resources are providing us the opportunity to build a system which can facilitate access to all three of these information sources for any user with a clinical problem to solve. As part of our IAIMS development, we are implementing and testing a system for servicing the query function for two types of users: researchers and developers of medical decision support technology and medical students during their third year clerkship in internal medicine.

These activities are directed toward (1) improving access to information about existing models of decision support technology (DST) and (2) facilitating the teaching of internal medicine as part of a third year clinical clerkship using a patient database coupled to an operational decision support system.

Part 1. Access to Models of Decision Support

The HELP system is a large computer-based hospital information system developed by the Department of Medical Informatics of the University of Utah for the LDS hospital in Salt Lake City, Utah. This system is fully operational at the LDS hospital and is being installed at the University Medical Center. It not only consists of a patient data file on which all hospital and medical functions depend, but also provides a data-driven decision-making function which operates from a file of decision frames developed by medical experts in a variety of areas. Under IAIMS support, four groups are presently expanding the HELP knowledge base in the following areas:

a. pain management by nurses
b. therapy decisions in patients with hip fracture
c. antibiotic use
d. hematological diagnosis

In addition, we propose to implement a clearinghouse function for information regarding the existence and current status of Decision Support Technology (DST) across the whole field of medicine. To accomplish this we have built a prototype many-to-many linked database. One file contains descriptive parameters for each DST, another file, titles in the literature which describe these DST's, and a third that has information about the experts who developed and maintain the DST. Medical and DST experts from many centers in the United States and elsewhere are being contacted and asked to identify DST's and specify the parameters to be used to describe each of them. Information specialists at the University of Utah are reviewing the pertinent literature, extracting the relevant parameter values for each model, and creating the links. Interested users may access this database via modem.

Part 2. Use of Decision Models for Education

We are exploring the use of decision models as a teaching tool using a particular DST (the HELP systems). This DST is coupled to a hospital-wide patient dababase which contains not only the data that contributed to each decision made by HELP, but also the decisions (interpretations) made on each patient. Another file contains the decision logic in the form of frames or modules that can be displayed in easily readable format.

Front-end programs are being built to permit easy perusal of this knowledge base and patient database for use as a teaching tool. In addition, we have begun the development of a set of special literature files that represent a subset of the literature considered most relevant for student needs by a member of the faculty who is experienced in a particular specialty area. To make it easy for a student to access these files to get information needed to solve a problem, we have developed a system called ILIAD.

Using this concept, a student may use a variety of word combinations in 'and' and 'or' arrangements to express a concept to be used in a query. This provides a mechanism for matching the thought processes of the person who stores information in a database and the person (someone else or the same person at a later time) who wishes to retrieve information. For example, information stored under the key words "subacute bacterial endocarditis" could be retrieved by entering "heart infection" if the system 'knew' that 'heart' included 'endocardium' and 'infection' included 'bacteria'.

Such knowledge is represented in ILIAD as a 'relation' consisting of a stem term (with or without synomyms) and its branches. The stem term 'heart' has as branches the terms 'endocardium', 'myocardium', 'pericardium', 'valves', etc. Branches are treated as alternatives ('or' terms) to the stem term(s) when performing a search. A branch term in one relation may be a stem term in another, thus allowing large heirarchial structures to be represented in this format. Thus, relations broaden the list of items retrieved and remove the constraint of requiring the searcher to specify the exact key word that was used by the person responsible for storing the item. By entering more than one keyword to specify a search, however, the list of items retrieved is narrowed again, but without as high a risk of missing the desired item since each key word has been expanded to include 'related' terms.

This approach has several advantages:

1. Relations can be entered after the fact—they need not be anticipated by the person storing the original data and can even be entered or modified at retrieve time.
2. Relations can be used interactively at retrieve time to allow user to limit a search to a subset of the branch terms.
3. An expert in a given area can supply relations for a database which will facilitate successful querying of the system by a non-expert.
4. A term may be part of more than one relation, thus allowing the database to express a variety of heirarchial structures. For example, a given diuretic might be related to other potassium-losing drugs in one relation and in another to drugs which are nephrotoxic.

Medical students will have access to literature databases selected by faculty and may build their own 'reprint files' as well using the ILIAD system. In the third year of the project, each student will have experience in building his/her own decision modules using knowledge derived from the medical literature. The effects on each student's ability to solve real clinical problems will be assessed as a function of his/her use of this system during the clerkship.

These are the prototype activities directly supported by the IAIMS grant from the National Library of Medicine. There are other activities not directly supported by NLM but vital to the building of a modern integrated information system on the medical campus at the University of Utah. These fall in three categories:

1. completing the installation of the HELP system in various departments of the hospital, and responding to the requests for expanded services.
2. installation of a network for basic science researchers who share programs and databases primarily around genetics and genealogy, and
3. coordination of efforts to install local area networks within most departments for both administrative and research purposes.

The IAIMS committee meets twice each month, and subcommittees are active as well in much the same way they were a year ago. We continue to sponsor meetings of small computer users and interest in our annual INFOFAIR is encouraging. We are hoping to get major support this year from one or both of two major companies interested in our IAIMS research.

Afternoon Session
Introductory Remarks

Harold M. Schoolman, M.D.
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Good afternoon ladies and gentlemen, and welcome again. In thinking about this afternoon's session, I remembered a very old story. As a matter of fact, this story is so old that I'm confident that most of you have never heard it. It involved an argument which was raging among the church elders as to whether or not they should buy a new candelabra. This argument had been going on for some time, and it reached a point which was generating a great deal more heat than light when one of the elders at an attempt to compromise and in a hope to avoid violence said, "All right, supposing we spend all this money to buy this new candelabra. . .is there anybody in the whole congregation that can play it?"

I think we have already heard some evidence that there are people in this congregation who can play it, but what we would be interested in pursuing this afternoon is the examination of what Fuchs called the technologic imperative. If you build a system, somebody is going to want to use it. And if you use it, what are the demands that are going to be made upon it? Demands in terms of resources, money, machines, people, etc. I think it would be foolish to think that we can answer those questions this afternoon, but we hope to be able to get a better insight into the questions, at least with regard to the implications of the introduction of the educational process into this milieu, "How do the educational programs become an integrated part of IAIMS Program?"

A good idea, in its implementation, is much more dependent upon the timing of its advocacy than its intrinsic virtue. Fifteen years ago, when the library started to work on its programs in support of medical informatics, we could have convened this meeting and held it in my office. As a matter of fact, we did. The environment has clearly changed enormously in the course of those 15 years.

As background to the introduction of some of the more specific activities that will be described by our speakers, we are privileged to have Dr. Swanson to give us the perspective of the AAMC and its studies and the current environment of medical education and medical computing.

Medical Information Science in Medical Education: A Transition in Transition

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The recommendation by the Panel on the General Professional Education of the Physician and College Preparation for medicine that medical schools should designate an academic unit for institutional leadership in the application of information sciences and computer technology to the general professional education of physicians and promote their effective use is frequently cited as a clarion call to employ information sciences and computer technology in medical education. The Panel's conviction that these could contribute to improving the education of medical students was based more on what were perceived as current defects in educational programs than on the Panel's knowledge about what information sciences presently has to offer.

The GPEP Panel's recommendation was based on a report of the Working Group on Fundamental Skills that was authored by Nina Matheson and Don Lindberg. The report focused on the skills that future physicians must have to manage effectively an ever-increasing data base so that their care of patients will be facilitated. Neither the skills working group nor the Panel itself gave significant attention to computer assisted instruction or the use of computers for evaluation of educational achievement. Although these applications may provide complementary educational support in the future, the fundamental concept is that medical students should use the tools of medical information science throughout medical school just as they now use books and journals. If and when that is accomplished, they will continue to use these tools through their graduate medical education and on into practice. Therefore, one goal I hope that the IAIMS grantee institutions are pursuing is the development of medical information management systems to be used by students in the course of their studies of both the basic and clinical sciences.

The greatest eventual gain could be a change in faculties' philosophies about their educational responsibility to medical students. At present, the predominant philosophy is that a medical teacher's job is to transfer information to students and to test their ability to recall what has been transferred. As medical information science matures, dependence on memory should be lessened and the reliance on data bases to facilitate rational problem-solving and decision-making should increase. Making the transition will not be easy. Indeed, we may have to await a new generation of faculty.

A recommendation in the AAMC's forthcoming report by an advisory committee on medical information science in medical education which states that medical informatics should become an integral part of the medical curriculum was attacked by some faculty members because it was viewed as an addition to the preclinical curriculum, which would take time away from the traditional basic sciences.

While faculties are reluctant to incorporate information sciences and the use of computers into medical students' education, the students are not reluctant to criticize this lack of emphasis. In the AAMC's annual Graduation Questionnaire, we ask the seniors whether they believe the time devoted to their instruction in several areas was excessive, adequate, or inadequate. In 1984 we added "use of computers" to the list. In both 1984 and 1985 over 80 percent of 11,000 respondents marked this area inadequate. That is the highest area of inadequacy targeted by students. It exceeds the next highest, practice management skills, by 10 points.

I thought it would be of interest to see whether the IAIMS schools scored significantly differently. Here are the results:

Johns Hopkins	66.2%
Georgetown	69.6%
Utah	77.8%
Harvard	80.0%
Maryland	81.6%
Cincinnati	82.4%
Columbia P & S	86.1%
Baylor	90.0%
Mean	79.2%

Although two schools have a significantly smaller proportion of their 1985 graduates who believe that the time devoted to computer use was inadequate, the mean for all eight is 79.2, just two points below the national score.

The introduction of medical information sciences into medical students' programs is at present largely through elective offerings, and this is growing. In 1984, 43 U.S. schools reported having electives in "computers in medicine." In 1985 the number increased to 58. In 1985 the AAMC's Organization of Student Representatives surveyed both U.S. and Canadian schools to obtain listings of computer-based courses and courses in medical information sciences. Sixty-five U.S. schools and five Canadian schools reported offerings ranging from one or two elective courses to large computer-based educational systems, such as those at Ohio State and Massachusetts

General. Of the IAIMS schools, four reported elective offerings for the 1985-86 academic year in the AAMC's Curriculum Directory. These were Harvard, Johns Hopkins, Georgetown, and Maryland. Two additional IAIMS schools indicated electives in their responses to the student survey. These were Utah and Cincinnati. Two did not indicate that they had elective offerings in either of the surveys. These were Baylor and Columbia.

The degree of penetration of medical information science into the academic woodwork of medical education is not great. Strategies to increase penetration are needed that go beyond elective courses. At present, however, I am not willing to say that there should be required courses because I do not believe the content and mode of presentation are yet clearly enough defined to determine how and when the education of medical students will be best facilitated by enhancing their use of this tool in their studies. I am apprehensive about incorporating information sciences as an add-on course. In my view such a strategy might achieve no more than adding a course in epidemiology and statistical methods to the second year curiculum.

Student and Applicant Information Management System (SAIMS)

An integrated academic management system should certainly serve the needs of students, but it should also serve the needs of the faculty in academic decision-making. In the remaining time I will describe the AAMC's Student and Applicant Information System, commonly known as SAIMS. The primary mission for all medical schools is the education of future physicians. It would seem axiomatic that this important societal obligation should be planned and executed using the best data possible about the characteristics of applicants and matriculants, the outcome of their education, and their ultimate careers.

Beginning with the entering class of 1978, the AAMC began building a data base that provides biographic, demographic, and academic information about every medical school applicant and matriculant in the United States. Data obtained during the application and selection process is expanded for those matriculated using our student record system, and a survey of graduating seniors completes the data through medical school. Subsequent to graduation, the type of specialty and program site of residency is added for each individual and changes in specialty or program during the course of graduate medical education are recorded through a tracking system. Ultimately, we expect to add first site of practice through linkage with the AMA's masterfile.

SAIMS is now operational. At the national level it provides for a continuing longitudinal study of trends in the characteristics of applicants and matriculants, the views of medical students about their education, and the career pathways they choose. For institutions, incorporation of these data about their own students into an academic information management system could support decision-making about the selection of applicants and modifications of educational policies and programs. To my knowledge, these decisions have rarely been based upon substantial information.

We welcome inquiries and are prepared to work with the IAIMS grantee schools and others to develop institutional data bases from the AAMC Student and Applicant Information Management System.

Remembering the 'A's: Report From the AMA Medical Student Section

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It was many years ago that the student leaders of the AMA's Medical Student Section recognized the almost limitless potential of computer application to improving the effectiveness, efficiency, and quality of medicine and medical education. We believed that computers could be used to enhance learning and facilitate the interaction and communication between teacher and student. We also knew that relatively few of the nations' medical students and physicians took full advantage of computer technology in their daily personal and professional lives.

We wanted to know why. We wanted to know what factors influenced student's perceptions and behavior with regards to computer use. We identified at least six important areas to consider in our informal study, inquiries, and formal surveys. These are what we call the six 'A's. They are: acceptability, availability, accessibility, affordability, applicability and ability. We had questions in each of these areas and developed a strategic plan to get the answers to our questions and act accordingly.

Let us talk about *acceptability.* In June of 1984, the MSS began planning a workshop for our December meeting. The topic was "Computer Applications in Medicine and Medical Education." We planned a seminar and handout to educate students on the basics, students gave demonstrations to show applications, there were different types and models of systems on display, and "hands-on" workstations so that students could come to their own conclusions rather than simply believing what we were telling them. The response was overwhelming. The meeting room was packed, and we ran well past the time we allotted for the workshop.

As Dr. Swanson stated, over 80% of the graduating seniors feel that their medical school's attention to instructing them on the "use of computers" is inadequate. As a senior, I agree. The only way that I could receive additional instruction on the computer was through our School of Public Health and by applying for a research grant. I did a research project with interactive video through the NHLBI. The data and our experiences seem to strongly imply that acceptability is not a problem. In fact, most medical students today have grown up in the "computer age" and see them as part of everyday life.

Our next question was *availability.* We did a survey of medical students attending our June meeting in 1985. We asked how many had a computer and modem available at home, at school, or at the hospital. The results were:

Available Computer and Modem	
20.8%	At their Home
72.7%	At the Medical School
46.8%	At the Hospital

We then asked them how frequently they used the computer and computerized information systems. They responded:

Use Computerized Information System	
13.0 %	Frequently
23.4 %	Occasionally
29.9 %	Hardly Ever
32.5 %	Never
1.30%	Did Not Respond

These results puzzled us. With so many computers around, why weren't they using them more often? We later asked that question and most students told us that while computers are available, they are not always accessible. Schools and hospitals placed unreasonable restrictions on use, did not provide what students needed, or when they needed it, or had only one or two terminals that someone else always seemed to be using; hence the problem with *accessibility.*

Our next question was on *affordability.* We believe that most students use a cost/benefit type of analysis for their use of computers as it compares to their other options. The most important factor is time. The perception is that it costs a great deal of time to learn how to use a computerized system. And of course, it can also cost a great deal of money for hardware, software, access time, paper and the like. Many students have concluded that the utility of available programs and applications is not worth the investment of their time and money; which brings us to our fifth point-*applicability.* We have confirmed that a system that has practical utility for a medical student will not only help him justify the expense of time and money, but seems to lead him to his own conclusion that he can't afford not to use the computer. In the past, the only useful and affordable application for students has been word processing.

Finally, we considered *ability.* As I alluded to earlier, there doesn't seem to be as much "phobia" about computers among medical students as we see in other segments of the population. Computers are accepted. Today, more entering students have had some experience with computers. The limiting factor for continued use is the misperception that learning how to use a computerized information system takes an inordinate amount of time. Therefore, most students are computer "illiterate." Now for the good news. Students who have taken the plunge, so to speak, by gaining some ability, report that computers are not only easy and fast to learn, but fun and exciting. Many report that they save time and money due to the increased efficiency and effectiveness of their work time on the computer.

Other good news, from the June survey I mentioned earlier, is that medical students want to use computerized information systems and they may be willing to pay for them. Our display table at the meeting included a variety of systems and "hands-on" demonstrations, as well as an area for participants to fill out the survey. We went over two of the questions earlier and we have two others to consider now. We asked students about 24 current or potential data base systems, medical communications applications, products and services. They were to rate them as to whether they would be useful or not useful to them as medical students. The results of these questions are below:

Data Base	Very Useful	Somewhat	Not Useful	D.N.S.
a. AMA Drug Evaluations Data Base	35.1	24.7	2.6	37.7
b. Drug Therapy Data Base	42.9	15.6	2.6	38.9
c. Disease Info Base (CMIT)	31.2	25.9	2.6	40.3
d. Current Proc Term Base (CPT)	10.4	23.4	22.1	44.2
e. Socio/Econ Biblio Info Base (SIB)	3.9	27.3	23.4	45.5
f. Clin Literature Info Base (EMPIRES)	32.5	19.5	6.5	41.6
g. MCH-CME Patient Simulation Modules	27.3	22.1	7.8	42.9
h. Medical News Service/Assoc Press	1.7	36.4	18.0	39.0

Medical Communications Applications	Very Useful	Somewhat	Not Useful	D.N.S.
a. Info from CDC, including MMWR	24.7	28.6	11.7	35.1
b. Referral info for devel disabled	10.4	33.8	15.6	40.3
c. Info from USPHS, incl P.H. Reports	14.3	29.9	11.7	44.2
d. CME course listings	10.4	28.6	19.5	41.6
e. Info from NIH and NLM	23.4	24.7	9.1	42.9
f. Electronic Mail	16.9	24.7	15.6	42.9

Products and Services	Very Useful	Somewhat	Not Useful	D.N.S.
a. Nat Boards/FLEX sample questions	68.8	13.0	2.6	15.6
b. Interactive Study Aids	27.3	27.3	9.1	36.4
c. AMA Dir of Resid Training Programs	71.4	7.8	1.3	19.5
d. AMA policy statements	26.0	44.2	7.8	22.1
e. Forums based on student interests	23.4	44.2	10.4	22.1
f. Employment opportunities	51.9	26.0	2.6	19.5
g. Info on housing for extramural clerk	59.7	18.2	2.6	19.5
h. Practice char (hrs worked, income)	45.5	29.9	3.9	20.8
i. Nat Dir of extramural clerk opport	74.0	6.5	1.3	18.2
j. Dir of financial aid services	59.7	16.9	3.9	19.5

We can learn from the responses to these questions in many respects. The clinical and pharmacologic data bases were the big winners in their category, while information from the CDC, NIH, and NLM were seen to be the most useful medical communications applications. Several proposed products and services received the greatest proportion of "very useful" responses. While nearly every item in this category scored well, three were particularly notable: National Boards/FLEX questions, AMA Directory of Residency Training Programs, and a national directory of senior rotation opportunities.

Finally, we asked students how much they would spend per month for a useful computerized information service. The results are as follows:

Dollars/Month	Percent
$ 0-5	14.3
6-10	23.4
11-15	7.8
16-20	14.3
21-50	7.1
Did Not Specify	31.2

We found it interesting and puzzling that such a large percentage of respondants chose not to specify an answer for many questions, so we asked some of them why. Most of the students that did not specify an answer did so because they were not sure what the computerized informations systems were and what they had to offer. They did not want to make uninformed judgements on the usefulness of these systems. They were more clear however on the usefulness of the proposed products and services presented, as the data suggests. The fact that a significant number of students would even be willing to pay for computer services, suggests that medical students may be a potential market for groups providing such services. These groups can be commercial interests, or more appropriately, the medical schools and groups like the AMA.

Now I'd like to bring you up to date on the efforts of the AMA Medical Student Section to "computerize" medical students. We have a designated Computer Services Liaison who heads our Committee on Computer Services and Utilization. The current liaison is Steph Treon, Ph.D., a fourth year student at the University of Pittsburgh.

The committee has investigated the ways that medical students currently use computers, and have developed new applications that were previously unavailable. The most common current use is for word processing. Medical students are using Appleworks and Wordstar, for example, to record and print their write-ups (History and Physical), class notetaking services, residency applications and concomitant personal statements. The obvious utility is the time-efficiency of modifying and personalizing an existing template as compared with conventional typewriting.

Data base management is another current use as some students are storing information and data on diseases and cases for later retrieval and study. Some are keeping personal records and catalogs of their scientific articles on disk. Our committee has developed two new utilities, the SEEPNET and the National Board Review Materials. SEEPNET is the acronym for "Senior Elective Exchange Program Network." A student can put the SEEPNET diskette into their PC and find a contact person at most medical schools in the country, who will either give them a place to stay, or help them find one when the senior is scheduling an extramural clerkship or an interview. Our newest utility has National Boards Review notes, lectures, and sample questions on diskettes for the personal computer. Telecommunications is another application used by medical students, though less commonly. The top leadership of the AMA-MSS uses electronic mail and modem to transfer data base and word processing files instantly. We find that this has significantly improved our communication and networking, and has even decreased some of our costs for phone and postage. Other efforts include negotiations within the AMA to make their medical information network more applicable and affordable to students.

Eventually, we want to create a nationwide network of medical students, or MSSNET, through the medical schools. We are starting to work with the AAMC Organization of Student Representatives (OSR) and their Advisory Board toward this aim. We will try to bring in AMSA's Computers in Medicine task force as well. We believe that our plans fit in perfectly with an IAIMS network at the medical schools. We hope to work with you on this in the future.

The "Take-home" Message is this:

- when planning and designing aspects of our IAIMS network that impact on students. . . INCLUDE STUDENTS. It is vitally important to get our input so that you may understand our perceptions, attitudes and expectations. Otherwise, I fear that you may be wondering why medical students aren't using the system that cost you so much time and money.
- try to REMEMBER THE SIX 'A's of medical student computer use, . . . acceptability, availability, accessibility, affordability, applicability and ability; but concentrate especially on affordability and applicability if you want to have the greatest impact.
- remember that in order to get students into our computer systems or networks, we must give them something they WANT. In order to keep them (and introduce them to the full potential of the computer), we must give them something they NEED. Our nationwide student network and the IAIMS network are just what the doctor ordered.

Medical Informatics Research and IAIMS: A Model for Long-Range Planning

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IAIMS planning must necessarily provide best estimates of the needs for resources anticipated for some time into the future. Long-range planning is always hazardous, but is particularly so in the IAIMS arena, because of the relatively limited time frame to date during which the health care professional has interacted directly with the computer. Such interaction is increasing not only quantitatively but qualitatively, at a very rapid pace, yet currently only scratching the surface of the potential capabilities for such interaction. Top-down planning for IAIMS is poorly equipped to foresee the impact of developments of such capabilities, which are largely occurring in the realm of medical informatics research. The purpose of this paper is to indicate the forms which some of these activities are taking, and to emphasize the need for active participation of medical informatics professionals in the IAIMS planning and development process.

To properly address this topic requires a bit of prophesying. We do so by describing our vision of the future, in terms of the information needs and practices in the academic medical center. Our vision is focused particularly on the next decade; in view of some of the more long-range impacts of technologies that are beginning to emerge, it would be hazardous to forecast much beyond this. Direct person-to-person video and video conferencing, for example, may ultimately have as much potential impact on travel and meeting attendance as do the automobile and airplane. They may profoundly affect the way we perceive our workplace and with whom we are able to collaborate, especially when combined with enhanced integration of digital information. Other technologies which we may expect to have major impact on our professional lives include the advances in networking, upon which video communication as well as other information transmission depends, the development of powerful personal computer workstations, with flexible user interfaces and high resolution graphical displays, and the appearance of extremely high volume and inexpensive mass storage, such as optical disks, which are becoming available for personal workstations.

Changes in our organizational and social structure that may result from such capabilities can be expected to evolve more slowly than the technologies themselves, and will probably only begin to take shape in the coming decade. For these reasons, we will take a relatively "safe" course of action (if predicting the future can ever be safe), and limit our vision to a ten-year perspective, extending through the mid-1990's.

Our objective here will be to describe a likely scenario for the future, and use this scenario as the basis for identifying the pertinent directions of medical informatics research. An understanding of these trends can aid in the selection of intermediate range goals for IAIMS that foster this scenario. Near term projects and pilot studies can be aimed at further clarifying these intermediate goals and identifying concrete implementation tasks. This should occur in an iterative fashion, in which experience gained with pilot and prototype projects and implementation tasks will create the foundations for subsequent steps.

Much is being written currently about the idea of a "scholars' workstation," a multi-potential desktop computer, connected via networks to a variety of other computers and data bases, and providing multiple kinds of capabilities to the user. Our vision, to be described below, elaborates on this concept, and seeks to refine it to reflect the particular needs of the health science professional.

Knowledge and Data

Much of the use of computers in the health sciences, and for that matter, in most fields, is involved in the task-oriented application of *knowledge* to *data*. Data arises in a variety of contexts, from patient observations and tests, from laboratory experiments, and from calculations, or it is extracted from pre-compiled data bases. Knowledge can exist in many forms, as *facts*, e.g., notes or textual information from experts, in books, in archival literature, in tables and compendia, in diagrams and pictures. It can also exist in the form of *methods* for carrying our specific tasks, as algorithms, rules, or analytic and statistical procedures. Thus a computer program is a form of compiled procedural knowledge. Finally, it can exist in the form of *relationships* between other knowledge elements; this is a kind of "metaknowledge" framework, exemplified by taxonomies and structures of bodies of knowledge.

Clearly, the distinction we are making here between data and knowledge is somewhat artificial. Data and knowledge span a spectrum or continuum. Manipulation or aggregation of raw data can produce new data, which represents a higher order classification or summarization than the original data, and may thus be considered a form of knowledge. An example is the recording of body temperature, a raw observation. If it exceeds some predefined limit, we may refer to this temperature as *elevated,* a higher order classification of the original observation. Thus, analysis and interpretation of data can generate new knowledge. At still other levels of decision making, however, such as diagnosis, elevated temperature is simply one of the raw data inputs. Procedures, as a form of knowledge, can also generate new data through calculations. Therefore, what we would classify as data versus knowledge depends on the perspective and the particular decision making need, and in that sense, the terms data and knowledge are relative ones.

Knowledge and Data Needs of the Health Care Professional

Despite the above difficulties in determining what we might consider as data versus knowledge, the health care professional must routinely access a variety of kinds of data, and must organize, review, and interpret it, determine actions based on it, and monitor those actions. To carry out these tasks, the professional must utilize knowledge, in terms of facts and methods, and known relationships among them.

The purpose of an information system to support the health care professional may thus be considered to be, in large part, to facilitate the coupling of knowledge and data, as required for the particular tasks the user is seeking to perform. The difficulty in current computer systems is that data and knowledge are often in diverse sites, on different machines, or accessible by incompatible programs. The user interface to them is inconsistent. There is essentially no tight coupling, except where it has been hand-crafted by an application designer.

Let us consider five general spheres of activity in which the health care professional is engaged, in which the task-oriented coupling of knowledge and data through information systems could be of direct benefit. These spheres of activity are depicted in the diagram in Figure 1:

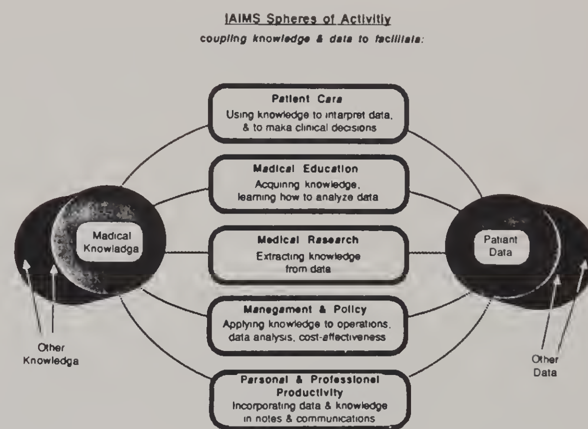

Figure 1. Five General Spheres of Activity in Which the Health Care Professional is Engaged, Within Which the Need for Task-directed Coupling of Knowledge and Data Arise.

1. *Patient care.* Tasks include accessing and organizing of patient data, analyzing and interpreting of data in relation to knowledge, recognizing deviations from normality, planning of workup strategies to assess deviations, and planning of therapeutic strategies to correct deviations.

To carry out the above task typically involves acquiring the raw data and observations directly from the patient or from the hospital or ambulatory care data base. This is often done in a manner specific to the particular institution and its computing capabilities. However, once the data are obtained, the tasks of organizing, analyzing, and interpreting data, and developing diagnostic workup and therapeutic plans involve obtaining or using a variety of other kinds of knowledge that are generally not particular to the institution. This may involve using procedures for presenting the data in flow sheets or graphical format that facilitate the identification of trends or patterns, seeking of archival knowledge about the meaning of these patterns or available strategies, and use of procedures for interpretation or for planning.

2. *Education.* Tasks include learning how to collect and organize data; learning the structure and vocabulary of medical knowledge (the metaknowledge framework); learning about the relationships among data, e.g., through functions, graphs, simulations; learning how to access knowledge; and learning how to apply knowledge to analyze and interpret data.

Data may arise in the clinical environment, as in patient care, or may be constructed and provided as problems or cases for the learner. The knowledge sources are again the facts, methods, and metaknowledge frameworks described above.

3. *Research.* Tasks include development of methods for collecting, organizing, and presenting data; development of methods for analyzing data; generation of hypotheses from data; testing of hypotheses with data; and extraction of new knowledge from data.

Data arise in the course of experiments, from observations or from instruments, including that generated by computers, or data precompiled in data bases. Factual knowledge is largely in the archival literature and textbooks. Much of the work of researchers is in developing procedural knowledge, testing it with the data, refining it, and then using it to manipulate and interpret the data.

4. *Management and policy.* Tasks include methods for capturing, organizing, and presenting data, analysis of data to assess operations, cost-effectiveness analysis, and methods for forecasting, modeling, and planning.

Data arise in the course of operation of the institution or facility. Knowledge consists of the facts and procedures for presenting, analyzing, and interpreting data to facilitate management and policy decision making.

5. *Personal and professional productivity.* This category includes those functions that are not related to particular patient care, educational, research, or administrative tasks, but which enhance the work environment and productivity of the health care professional. Tasks include methods for management of time and resources (e.g., scheduling, planning of meetings), methods for communication with colleagues (electronic mail, video conferencing), methods for exchanging data, methods for accessing knowledge, and methods for incorporation of knowledge and data in notes and communications.

Data may arise in any of the other spheres of activity of the professional, or may relate to personal schedules, budgets, telephone directories, etc. Knowledge consists of those facts and procedures which are needed to utilize such data, maintain it, and communicate it.

Information System Interface Requirements

One of the distinguishing characteristics of the use of computers by the health care professional is that such use typically encompasses multiple functions, rather than just one or two. Most individuals could benefit from use of a computer for several activities within any particular one of the above five spheres of activity. In addition to their general need for personal and professional productivity support, individuals are most likely engaged in multiple other spheres of activity, combining patient care, educational, research, and/or administrative responsibilities. As a consequence, there is little opportunity to become proficient at any one function, as is possible for a clerical worker using a word processor continually, or a financial analyst using a spreadsheet. Rather, the health care professional is faced with a variety of tasks that must be performed, not only sequentially, but often concurrently, with digressions to take care of other matters as required. These considerations impose several desiderata on the nature of the ideal interface between the information system and the health care professional[1]:

Consistency. A computer system interface for the health care professional should be one that presents a consistent and uniform "front end" for the various tasks that must be performed. Whether the tasks involve fetching of data from a hospital computer, interrogating an on-line bibliographic service, or running an analytic graphical display procedure that is provided on the personal workstation directly, the user should be able to operate these programs in a consistent manner. The system should operate in such a fashion that the user is able to remain unaware of what was required by the computer to extract the relevant data and knowledge from its various sources. In other words, the workstation should be the engine for "coupling of knowledge and data" in a way that is transparent to the user, and aimed solely at facilitating the performance of the tasks the user requires. The user should not need to "change modes" continually, to learn hosts of specific conventions for operation of individual programs.

Integration. Another key feature of the user interface that is implied by the above is that the various tasks of obtaining data, organizing it, analyzing it, interpreting it, and presenting it, which involve the application of knowledge in terms of facts and procedures, should not need to be operated as totally separate entities. Results of one function are often the raw data for another. Procedural knowledge is typically embodied in a computer program that expects data to be provided to it in a standard form, either from a data base or from user input. Factual knowledge that may be valuable to a user analyzing data should be able to be obtained while the problem is "hot." For this kind of harmony among tasks, the various programs performing the tasks must have standard interfaces with each other, and be developed with an aim of ultimate integration. The "Integrated" in IAIMS refers to this need.

Much functionality of the kinds described above, in the discussion of the five spheres of activity of the health care professional, already exists in various forms, in various computer systems, many of which are in operation at various medical centers. However, the functions are not integrated with each other into a harmonious whole, nor available in a uniform fashion.

Concurrency and Digression. Another characteristic of the health care professional is the need to perform several tasks concurrently, or at least be able to temporarily suspend one task while performing another. This is true of one's daily activities, even when not using a computer, for example, while engaged in writing a manuscript, but interrupted to answer a telephone call, or to schedule an appointment, or when one wishes to look up a reference needed in the manuscript. Patient care is similarly interrup-driven: data are collected and subsequent tasks are generated for collecting additional data, seeking information from the literature, or analyzing results. These tasks often need to be pursued more or less concurrently, and with differing time scales, and requiring attention as each task is completed. The computer system interface for the health care professional must similarly support such concurrency and digression. While involved in reviewing patient data, one may wish to file a personal notation, retrieve relevant knowledge from an on-line text or from the literature, look up a drug's characteristics in a data base, or send a message to one's colleague. The ability to temporarily suspend what one is doing, and to do something else that is either relevant or not, is the way we normally function. The computer system needs to provide an environment that matches this characteristic.

A Vision of the Future

We are now ready to describe our vision of the computing environment for the health care professional. This environment is one that fosters the coupling of knowledge and data, in order to facilitate the tasks of patient care, medical education, research, management and policy, and personal and professional enhancement. General computer interface features that are considered most important for the health care professional are those of consistency, integration, concurrency, and digression.

Specific elements of this vision are the following:

The professional workstation. A major premise of our vision is that the desktop workstation will become an essential appliance for the health care professional. The workstation will provide access to both "built-in" factual and procedural knowledge and personally maintained data (accessible totally from within the workstation and attached storage devices), and also to data and knowledge that are obtained (through linkage via communication networks) from other local and remote computers. The coupling of knowledge and data from diverse sources will occur in a fashion that is largely transparent to the user. Software contained within the workstation will be responsible for providing the functions of consistency, integration, concurrency and digression, and for supporting access to the various data and knowledge sources required by the specific tasks the user is performing. Workstation technology is evolving rapidly to provide both hardware and software environment support for this vision. The major task will be to develop new applications, and adapt existing ones, to perform specific functions within this hardware and software environment.

The network. Both individual workstations and shared computers will be interconnected through a common communications network, connections to which will be as unbiquitous as the telephone jack, the so-called "information jack." Such network technology is evolving rapidly currently, at the hardware level, involving both coaxial cable, fiberoptics, and microwave technologies. Software for matching the characteristics of individual computers, and translating them to compatible standards is being built into the connection points to networks. Higher level understanding of the contents of data and knowledge, transmitted over these networks, is generally not as well agreed upon, and is usually the responsibility of the sending and receiving computers.

Servers. A server is a device that has a more or less specific set of functions that it can perform, in a network environment, for which it receives requests from other computers. Examples of servers currently available on networks are data base servers, that handle the storage and retrieval of data in data bases that need to be accessed by a variety of users; print servers, that handle the printing of files on specialized output devices such as high speed line printers, laser printers, or microfilm; image archiving servers that handle the special image storage, compression, and processing needs of images such as radiographs and micrographs; graphical output servers that produce high-quality plots and charts, on paper or on slide or video format; and network and gateway servers, which facilitate locating of particular users or servers, which may be on the same or different networks, handle interconnections among them, manage the traffic on the network, and maintain network operation.

We foresee that multi-user computers, such as those currently in various hospitals, ambulatory care facilities, libraries, research facilities, and computer centers, or computers available through dial-up such as bibliographic search services or other information utilities, will evolve into servers in a network environment. These multi-user systems now primarily support users at terminals, either dialing into them or directly connected to them. We envision that these systems will evolve to providing primarily data base server capabilities. Rather than using multi-user computer through a terminal, to run a variety of programs that are executed on the central computer itself, to access the data base on the central machine, users will access the central machine through their workstations. Requests for specific data will be generated from the workstation, sent via network to the appropriate central machine, now functioning primarily as a data base server. The server will select the appropriate data and forward it to the requesting workstation. Once analyzed, any results or additional data will be sent back from the workstation to be filed in the server's data base. Thus the programs responsible for analyzing and interpreting data, collecting new data, or accessing data or knowledge which may be elsewhere (in local optical or magnetic disks, or obtained via access to other servers) will reside primarily on the local workstations. Other specialized analytic procedures may still reside on central machines, which in effect become analytic servers for those particular functions.

How Do We Get There from Here?

The above vision of the future depends to a large extent on recognition of both needs of the health care professional and capabilities of the technology to support them which we can expect to see available in the next decade. IAIMS projects should not seek to duplicate computer hardware, networking, operating system, or programming language developments occuring in multiple places currently, with resources dedicated to these activities. It is reasonably clear that the "scholar's workstation," as presently evolving at Carnegie-Mellon University, Massachusetts Institute of Technology, and in a variety of other university and corporate sites will provide an adequate technological base for such developments. Network technology is also moving ahead well.

Rather, IAIMS projects should select from those developments, encourage cooperative arrangements with certain developers, explore alternatives to determine strategies that seem to be effective, and develop applications for this kind of environment. If successful, such projects can establish useful convention for design of new applications and guidelines for the interface of existing multi-user systems to the workstation/server environment.

A major effort should be devoted to identifying how a user should interact with the computer in terms of the applications integration capabilities that are needed. For example, when a patient's laboratory test data are retrieved from any hospital or ambulatory care data base, we need to determine what kind of organization and presentation of the data, e.g., in flow sheets or graphs, would be useful, and make these directly accessible and integrated with the application that requested the data from the data base server. We need to do this kind of application-specific identification of data and knowledge sources in all five spheres of activity (patient care, education, research, management and policy, and personal and professional productivity), and to build an environment for the user that is "task-directed." By this we mean, in the context of dealing with a specific problem or task, all of the relevant operations that may be desired are made readily available to the user.

Role of the Medical Informatics Professional

Clearly, if one accepts the long-range vision of IAIMS described above, there is a large research agenda ahead of us. Implementation of systems fulfilling this vision will not be done overnight, nor is the vision proposed here necessarily widely shared. However, it is probably fair to state that the Medical Informatics research community is currently engaged in a number of activities that relate to this view. To the extent that this is occurring, IAIMS planning can greatly benefit from a close relationship with the Medical Informatics professional. Failure to do so will necessarily cause IAIMS planning to be somewhat short-sighted, at a time when the impact of current qualitative changes in the computing environment are only dimly able to be foreseen.

A number of other benefits accrue from a close relationship between administrative planning for IAIMS and academic Medical Informatics activities. IAIMS issues provide a rich problem area for Medical Informatics research, as indicated by the above. IAIMS planning and policy issues also provide important experience for the Medical Informatics professional, furthermore. Academic units of Medical Informatics, which are beginning to come into existence at medical centers, as urged by the GPEP report[2], will need to have input into, and work with administration, in determining information policy and resources. Individuals in the field of Medical Informatics will often, as has been true in the past, combine careers involving research, education, and service, and will sometimes find themselves with planning and policy responsibilities[3]. As the primary academic liaison to other health care professionals about Medical Informatics issues, the Medical Informatics professional will also need to be responsible for faculty and student education, and for identification of informatics needs of these communities.

As director of one of only five NLM-funded post-doctoral training programs in Medical Informatics nationally, I must point out that the current training opportunities in Medical Informatics are extremely limited. Yet as can be seen from the above, the need is great, and we must address this shortage soon, if the IAIMS effort is to achieve significant impact.

Another point must also be addressed. Much of what IAIMS seeks to provide is still very much in the research and development stage. The costs of moving these research and development efforts into operation are frequently overlooked but very large, probably multiples of the original research and development costs. IAIMS will be an expensive undertaking, which will require both long-range research and development, and substantial funding for translating these developments into operational systems. Creative ways of funding such activities must be found.

Acknowledgments

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The Use of Information Technology in an Experimental Curriculum at Harvard Medical School

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It is obvious that very dramatic changes are occurring in medical practice: changes initiated by advances in biomedical knowledge, changes made possible by innovations in technology, and changes demanded by new patterns of practice and new forms of reimbursement. (Figure 1) The present graduate education of the physician is poorly suited to prepare the medical student of today to become the physician of the twenty-first century. The medical school curriculum must prepare medical students to learn throughout their professional lives rather than simply to master current information and techniques. A recent report from the Association of American Medical Colleges (the GPEP Report)[1] discusses many of these new forces and strongly recommends that medical schools undertake a fundamental reappraisal of how physicians are educated.

New Pathway — Harvard Medical School

Why?

1. **Increasing complexity of medicine of future**
   - **Advances in scientific discovery and technological invention**
   - **Aging of population with shift in burden of illness from acute toward the chronic**
   - **Emphasis on cost containment, at the expense of the promotion of quality and accessibility**
   - **Increasing corporate nature of health care delivery with increasing complexity of financial arrangements and relations between health care professionals**
2. **Present curriculum is too strongly passive and lecture-based**
3. **Memorization of great amounts of factual information is stressed**
4. **Fragmented curriculum with responsibility divided between departments**
5. **Lack of recognition of medical students being adult learners**

Figure 1.

Harvard Medical School has initiated a new curriculum — called the "New Pathway" — which involves a basic restructuring of medical education and a greater emphasis on problem solving and independent learning. (Figure 2) In September, 1985, the New Pathway program started with a group of 24 students selected from the entering class of 165 students. The 24 students will remain in this separate New Pathway curriculum for the total four years of medical school. In September, 1986, 38 new first-year students will begin the New Pathway program.

New Pathway — Harvard Medical School

What?

1. **Single faculty control**
2. **Small group, problem-based, self-directed learning**
3. **Equal emphasis on attitudes, skills and knowledge**
4. **Select "essential knowledge" to avoid information overload**
5. **Interweave clinical and basic science throughout curriculum**
6. **Acquisition of skills in information management**
7. **40% Elective Time — thesis required**
8. **Emphasis on students becoming lifelong learners**

Figure 2.

The New Pathway makes extensive use of active educational methods such as problem-solving and information management, self-paced learning, and small group discussions. In the New Pathway, there are few lectures; instead there is more emphasis on the student assuming individual responsibility for his/her own education. One of the key elements of the New Pathway curriculum is the intensive use of information technology as a primary educational and information management resource to assist the student in the mastery of the scientific basis of medicine, and in the development of problem-solving skills. This paper discusses the use of information technology in this experimental curriculum and describes several of the computer-based educational modules which have been developed.

Technical Description

In 1984, Harvard Medical School received a five-year grant from Hewlett-Packard Corporation to provide an integrated computer network to support the communication and information processing needs of the New Pathway students and faculty members. Each student and each faculty member has access to a computer for personal use; in addition, there is a telephone communication network which supports sharing of information among the different computers. This computer technology is used to provide increased access to the knowledge base of medicine both through an automated bibliographic reference capability and through the development of innovative computer-based programs to access medical knowledge bases. The individual students and faculty members of the New Pathway are the first medical school class anywhere in the world for whom computer technology is such an integral part of the educational experience.

By the end of September, 1986, over 160 Hewlett-Packard personal computers or terminals will have been installed in the homes and offices of the New Pathway students and faculty. These computers communicate with the central system (an HP 3000) via modems connected to dial-up telephone lines. (Figure 3) All communication between the 3000 and the personal computers is done over standard voice-grade telehpone lines. The decision to use telephone communications was based on the geographical distribution of the New Pathway user community. About half of the students live in the dormitory on the medical school campus; the other half live in apartments scattered through the surrounding communities. Faculty members have offices located in almost a dozen different medical institutions separated by a considerable distance in the Boston metropolitan area, and a number of faculty prefer to have their computers located in their homes rather than in their offices. Telephone lines were the only feasible way of connecting such a widely scattered group of users.

New Pathway — Harvard Medical School

TECHNOLOGY HP 3000
- **Model 48, 4 Meg memory**
- **2 404 Meg disks**
- **10 modems, 8 direct-connect ports**
- **Runs HP Desk only now**
- **HP trying to implement MUMPS for central data base activity**

HP 150 - 640 K memory, 15 Meg disks, Thinkjet printer, modem
- **At present 40 150B, 40 150C**
- **All application software written in MUMPS**
- **136 users - many with their own personal computers**

VECTRA - 640 K memory, 20 Meg Disk drives
- **40 first year students next year HMS (and each succeeding year)**
- **30 MIT HST students next year (and each succeeding year)**
- **Supplement with 2392A Terminals for Electronic mail only**

Network with Harvard University Project Athena (MIT)

TOTAL PERSONAL WORKSTATIONS 1988 = 400-700

Figure 3.

The New Pathway users vary widely in their level of familiarity with computer technology; only 5 of the 24 first-year students had significant prior experience with computers (usually word processing). We provide a spectrum of support services that users can take advantage of as needed in their work with the PC's. Several hours of group instruction for students are held at the beginning of the academic year. Faculty members, who receive their computers at varying times during the year, can request individual training sessions. In addition, technical staff are available by telephone for specific questions about the computers on an on-going basis.

We did not anticipate the degree of impact the ready availability of electronic mail would have on the educational experience of both faculty and students. Originally we believed that electronic mail was a relatively trivial application and that it would have little educational value. This concept has proven to be a gross underestimation of the worth of electronic mail; we now consider this application one of the more important elements of the information technology support. In one typical four month period during the first year the total number of accesses by individual students varied from 34 to 258. During one sample three day period, all of the 24 students logged on at least once, and 15 students accessed the system on all three days.

The faculty uses the system for planning and developing the curriculum materials and cases, and for communicating with other faculty and with the students about specific course questions. Because of the geographic dispersion of the Harvard Medical School faculty, curriculum planning and development in the past was typically associated with many hours wasted in commuting to committee meetings and in trying to communicate by phone, often playing "telephone tag" — leaving messages to call, not being available when the return call is made, etc. The increased efficiency of the communication and information sharing among the New Pathway faculty made possible by electronic mail has come to play an important role in curriculum development, and, more importantly, has strongly influenced how the teaching sessions are planned and how the different tutorial sessions are implemented.

The students use the system for sharing ideas about the curriculum assignments, personal interactions, and questioning the faculty. The students, as well as the faculty, believe that electronic mail facilitates faculty and student communication and cooperation in a community which may not have daily face-to-face contact. They feel that the intellectual "networking" made possible by the electronic mail system greatly improves the educational experience and makes it more enjoyable.

Medical Education Modules

The computer-based New Pathway medical education programs are developed and implemented as a series of modules that are incorporated into the curriculum as integral elements of the total educational experience. It should be emphasized, however, that the NP curriculum is NOT just a set of computer programs; the computer support is only one aspect of a much larger commitment to self-directed learning. The role of the information technology is not to replace faculty contact but to facilitate faculty-student interaction and to enrich and

extend the learning environment of the student.

The dominant challenge in the application of information technology to medical education is the development of software. There is a paucity of outstanding medical educational programs, and much of that which is available is often poorly documented, difficult to modify, and written in computer languages which we do not support. There are six major classes of software being developed for the New Pathway: (1) file management applications related to medical knowledge and patient records; (2) programs which facilitate vocabulary acquisition; (3) data base access applications; (4) test-bank questions; (5) basic science teaching programs based on physiology simulations; and (6) clinical teaching programs based on case-management simulations. A number of programs developed for the New Pathway are now in active use by the students; others are still in the prototype phase and are not yet integrated into the curriculum. In order to illustrate the strategies and the design criteria, three of the educational modules are described below:

1. File Management Applications

An important goal in the New Pathway philosophy is to stimulate the students to efficiently and effectively manage their own learning process including the recording of one's educational experiences. The typical medical student uses 3×5 cards and a pocket notebook to record key references, "pearls", course notes, useful source references, etc. The Personal Reference File is a support program which is now being developed in order to provide a computer-based solution that combines the functions of a personal notebook, personal filing system, and a clinical case book.

An important component of the Personal Reference File is a standardized hierarchical vocabulary to index each record. This vocabulary is based on a terminology developed by the National Library of Medicine to index medical literature. We believe this vocabulary known as MeSH (for Medical Subject Headings) is a good model for organizing the medical knowledge base. The 15,000-term vocabulary is implemented on each student's personal computer as a "window-driven" set of displays. Within each window, the student can move up and down through the tree structure. Once in the tree, the user may call up at any time a map of the path from the base of the tree to the current term. The student can request information about other locations within the nomenclature which contain related terms. It is also possible to view all contexts of a term within the model and switch between these contexts. The use of this controlled vocabulary facilitates selective retrieval of information from the Personal Reference File, and allows students and faculty to share notes and references that are relevant to the same topic.

We plan to use this same strategy in the development of a Clinical Case Book which can be used by the student to record a minimal description of each patient seen by the student. We will extend the MeSH vocabulary to provide the capability for the student to use a controlled nomenclature in recording these clinical terms. This primitive medical record provides practice for the student in recording and retrieving medical record data using a computer system, and allows review of the clinical experiences of each student to identify areas where there are gaps in the educational experience.

2. Data Base Access

A central theme of the New Pathway is the promotion of student-directed learning using a variety of educational resources; thus it is expected that the student will become skilled in accessing the published medical literature. A major limiting factor is the sheer volume of published articles of interest. More than 3,000 journals containing more than 17,000 articles are indexed each month in the standard National Library of Medicine MEDLINE file of bibliographic references which now contains over six million references to articles published in the United States and seventy foreign countries since 1965. Even though Harvard Medical School has a large and easily accessible medical library, time limitations often make it difficult for the student to locate and read appropriate articles or textbooks.

All New Pathway students are provided access to a national, computer-based, on-line information retrieval system — BRS/Sunders COLLEAGUE — which contains both the complete MEDLINE file provided by the National Library of Medicine and also full text files of many of the more important journals and textbooks. Computer programs have been written to allow the students to use their own computer and modem to access these files through a national communications network. This provides them with an extraordinary opportunity for easily accessing the medical literature and makes possible a self-directed learning through taking advantage of different knowledge bases in medicine.

3. Computer-based Test Bank Questions

The educational strategies of the NP curriculum are designed to promote independent learning and self-assessment. Student evaluation is competency-based and accomplished through regular formal evaluation procedures. In addition, all students are required to take the National Board of Medical Examiners (NBME) tests. As part of an informal self-assessment of knowledge acquisition on a continuing basis, and as part of the preparation for the NBME tests, a computer-based test bank of questions has been prepared.

This test bank does not simply score on a right/wrong basis but provides active feedback and interpretation as to the validity of the different answers. The item bank includes questions which are multiple-choice assessment of factual recall and also questions that challenge the student with problems of interpretation and integration of information in problem-solving situations. Clinical simulations of patient cases will also be used to evaluate the student's ability to deal with complex clinical data. It is not intended that this test bank will be used in formal evaluation of the student, but rather that it will provide check-points to assist both the faculty and the students in assessing the successful acquisition of factual information and clinical problem-solving skills.

Evaluation

The evaluation of any innovation in graduate education is difficult since the students involved in the inovation are so heterogeneous in background and skills, and their performance is so strongly influenced by factors other than the specific details of any change in the curriculum. Evaluation of the information technology innovation in the New Pathway is particularly difficult since the overall objectives of the new curriculum are not specifically concerned with student performance on any test of factual knowledge; rather the goal is to stimulate the students to acquire the total set of skills, attitudes, and knowledge that will result in their becoming competent and caring physicians in professional careers covering the next several decades.

Thus far, the only specific evaluation of the information technology aspects of the New Pathway is a student questionnaire that was completed by the first year's class at the end of the first academic year of the new curriculum. The questionnaire requested the student to rate a number of the computer-based applications according to the following scale:

— 7 = this application of extraordinary value; my medical education is of significantly greater value because of the availability of this application

— 6 = this application of great value; it should be supported and extended if possible

— 5 = this application of value; I find it useful

— 4 = this application of some value, but not high priority

— 3 = this application of little use to me

— 2 = this application of no use

— 1 = this application is distracting, a time sink, recommend it be terminated immediately

— X = I have not used this application sufficiently to make a judgment

The list of applications to which the rating scale was applied included: Electronic Mail, BRS/Sunders COLLEAGUE Access, Word processing, Test Item Data Bank, Physiology Simulations, and Patient Simulations. Twenty-two of the 24 students returned the questionnaire. Table 1 summarizes the results.

Table 1.

	No. students who rated the Application	Range of Rating	Average Rating	No. students who rated 6 or 7
COLLEAGUE	22	5-7	6.8	21
Word Processing	22	5-7	6.2	19
Electronic Mail	22	5-7	5.9	15
Physiology Simulations	19	3-7	5.4	10
Test Item Bank	16	2-7	5.4	9
Patient Simulations	15	3-7	5.1	5

We interpret the results to mean that most of the modules are felt by the student to have a very high educational value. We believe the evaluation by these students is relevant and important, for these are students deeply committed to their own education and very cognizant of the enormous amount of knowledge and skills that must be acquired in a very short period of time.

In the initial planning of the New Pathway there was concern that the use of the computer technology might interfere with the personal communication among the students and between students and faculty. We asked the students to consider this issue a separate question. Of the twenty students who responded, sixteen chose the response: "The computer system and network capabilities have significantly improved and enhanced the communication I have with my fellow students and with the faculty," while the remaining four students chose the response: "The computer system has somewhat improved and enhanced the communication." This strongly suggests that our initial concern was not only groundless, but that, in contrast, the students perceived that the computer system enhanced the level of communication.

Conclusion

Information technology offers an important potential to significantly improve the medical curriculum and to help the student learn skills which will become increasingly important in the practice of medicine. We are persuaded that a valid response to the problem of "information overload" is to take advantage of computer technology to facilitate student learning and continuing physician competence. We believe that easy access to computer-based educational applications will promote the student's acquisition of the essential knowledge and mastery of the necessary problem-solving skills. We also believe that a indepth experience with modern methods of information management will enhance the effectiveness of the New Pathway graduates when they enter into the practice of medicine.

The New Pathway at Harvard Medical School has made a very significant commitment to the use of modern information technology in a new curriculum. The generous support of Hewlett-Packard has been a key factor in making it possible to implement a very ambitious experiment in the use of information technology in a variety of applications in this curriculum. The first few computer-based educational modules have demonstrated considerable promise and have been well received by both students and faculty. The major challenges in the next few years are to develop a broad spectrum of such modules, to continue to enhance data management capabilities for personal reference files and computer-based medical records, and to fully integrate these modules into the curriculum so that maximum effectiveness can be achieved.

The development of educational software and the optimal utilization of computer technology is an iterative process. We have learned much, but are keenly aware of how much remains to be done. We must address the most difficult issue of attempting to measure the effectiveness and efficiency of student learning in this new environment, as well as the real costs involved. It is premature to make a quantitative assessment at this time; however, all of us involved with the effort are very encouraged by our experience thus far. We believe that the New Pathway has exciting and promising objectives, that powerful technology is now available, and that the time is appropriate to proceed with the full exploitation of this technology.

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Medical Informatics in Medical School: Should We Teach Concepts or Procedures?

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At the University of California, San Francisco (UCSF), we are in the midst of developing a curriculum in medical informatics for undergraduate medical students. This undertaking gradually came about for a number of reasons:

1. Several of our faculty had independently recognized that undergraduate medical students could greatly benefit from the technology of modern information management if they were more familar with it. They suggested that this subject be systematically taught in the required curriculum.
2. At the same time, other faculty were recognizing (as had the AAMC), that a leading complaint of graduating medical students for several years was the lack of training in the use of computer technology, and finally,
3. We have had a graduate program in Medical Information Science at UCSF for the past 15 years, which provided a focus for issues related to medical informatics.

The co-existence of these factors, combined with the stimulus provided by the GPEP Report, led to the development of a proposal, and its acceptance by our Curriculum Committee, that components of medical informatics be made a part of the required course work of the undergraduate medical curriculum.

In choosing among the possible curricular materials and methods, we were influenced by the work of the AAMC Study Group, and especially the early proposals of Lindberg and Matheson. These included their recommendation for an organizational focus for medical information science in medical schools, and their stipulated levels of accomplishment in medical informatics. An appreciation emerged of the advantages to be gained by introducing this new material in existing courses at times and places where the context makes this especially appropriate. This admittedly piecemeal approach avoided some of the problems of finding space in the existing curriculum since several courses contain material which could be reintegrated with medical informatics subject matter. The disadvantages of this approach are that it is less efficient, consumes more teaching resources, and if its thrust is not to be dissipated in generalities, a single administration must be found to provide direction and continuity.

Outline of Curriculum

The general shape of the curriculum is now beginning to appear. We will add new materials in the introduction to clinical medicine (ICM) courses in both the first and second years. In the first year, there will be a brief introduction to the principles of medical information science, an overview of medical computing systems and demonstrations of current applications systems (history taking programs and bibliographic searching programs). The syllabus for the second year will include demonstrations of diagnostic prompting programs such as RECONSIDER and QUICK, and students will be able to work with bibliographic and full text search programs. Since the students do not meet as a single group in the third year, and because of the applicability of formal decision making methods to their activities in the clinical clerkships, decision analysis will be introduced to small groups of students in seminars or weekly clinics in the clinical departments of the teaching hospitals. Sessions in the fourth year (given to the class as a whole) will be devoted to an update and summary of modern information methods applied to medicine.

Is Medical Informatics a Science?

As a by-product, these curricular activities have prompted the question as to what medical informatics really is. Is it more than a bag of tricks? Does it represent a new and emerging science or is it applied computer science or engineering? What do we propose to teach our students? Some of us believe the answer to these questions is that medical informatics is the science concerned with the properties of information, and that our increasing knowledge of these properties will provide important insights into the nature of medicine and its practice.

Let me attempt to make the case for this viewpoint by considering a single example. A remark of Niels Bohr suggests how we might begin;

> "It is wrong to think that the task of physics is to find out how Nature is, physics concerns what we can say about Nature."

In a similar way, medical informatics is concerned with what we can say about medicine. Since both medical informatics and medical education are concerned primarily with scientific information, the need to understand the properties of scientific information provides the connection between the two. It is this connection, that enables each to influence the other.

Informational Aspects of Medical Education

Medical schools transfer to their students large numbers of facts but relatively few rules. Because of this, medicine has been said to be "long on facts and short on theory." Since both clinical experience and the research enterprise produce facts far more rapidly than they can be incorporated into the fabric of medical knowledge, the amount of unintegrated (undigested?) medical information continues to increase.

This connection between medical informatics and medical education can be seen by considering how we introduce the results of medical research to medical students. Or, as Bohr might put it, — what is it that we can say about medicine? An example of what is involved here is suggested by Figure 1, a sample of the topics students might hear about in a single day:

Organelles	Angina	Burns	Legs	
Bacteria	Hypertension			
Livers	Molecules	Unconscious		
DNA	Fat	Vitamin C	Spongiosis	Acid
Bones	Aspirin	Neonatology	Fear	
Brains	Enzymes	Jogging	Sartorius	LDH
Ions	Organs	Pain	Nutrition	
Metabolism	Necrosis	Fractures	Sorrow	Ribs
Present Illness	Trace Metals	ECG	Depression	

Figure 1.

It was argued some years ago that a computer program supplied with a million facts would behave intelligently, and in medicine it has been proposed that a million facts would suffice to capture the essence of internal medicine. If this should turn out to be the case, 100,000 charts like the foregoing would be required to form a complete index to internal medicine. But something absolutely essential would still be missing. To teach medicine in this way leads to what our former chairman of medicine, Holly Smith referred to as the "Cuisinart" method of medical education. By this is meant extracting the integrated medical knowledge which is present in one mind, chopping it into bits and transferring it into another where it must be re-integrated again. And this mysterious re-integration must proceed without benefit of rules or theories. The surprising thing is that this procedure actually works (most of us learned medicine this way), though this may be more a testimony to the versatility of the human mind than the result of pedagogical insight. This conversion of data into information and knowledge is the task of medical education, and understanding these processes is a prime concern of medical informatics.

We can make this connection between medical informatics and medical education clearer, by applying a simple taxonomy to the above elements. We know that the declarative information of medicine (its fact statements) can be regimented in many ways, and we are meeting today in one of the world's foremost institutions for doing just this. Consider the following as an example of how we might arrange the things we need to speak about in medicine (Figure 2).

People	Angina, Unconscious, Fear, Pain, Sorror, Depression
Body Parts	Burns, Legs
Organ Systems/Organs	Livers, Bones, Brains, Organs, Ribs
Cells	Bacteria, Spongiosis, Necrosis
Organelles	Organelles, Metabolism
Membranes/Fibrils	
Biopolymers	DNA, LDH, enzymes
Molecules	Vitamin C, Aspirin, Fat
Atoms	Trace metals, ions
Elementary Particles	

Figure 2.

This particular arrangement consists of the sequence in which the objects of medicine when taken apart — literally, not figuratively — yield the components shown on the line immediately below. The resulting hierarchical series displays the part-whole relationships of natural objects and suggests a means for organizing scientific knowledge. It is important to note that this arrangement is not an arbitrary scheme of librarianship, nor a statement from an abstract theory of classification. It is a scientific statement, an empirical claim about the way the world is organized and it could not have been made 50 years ago. This statement also identifies the scientific disciplines with which medicine is most concerned and

indicates the relationships. When the details of Figure 3 are filled in, the diagram also shows where the gaps in our knowledge are.

People	Clinical medicine
Body Parts	Clinical medicine
Organ Systems/Organs	Physiology
Cells	Cell biology
Organelles	Cell biology
Membranes/Fibrils	Cell biology
Biopolymers	Molecular biology
Molecules	Biochemistry, Chemistry
Atoms	Physics, Chemistry
Elementary Particles	Physics

Figure 3.

By using this taxonomy (Figure 3), statements about the world can be organized into subjects and disciplines, and the responsibility for integrating and managing knowledge can be allocated to the corresponding specialty. It is then up to the chemists, for example, to decide what chemistry consists of. But this doesn't explain which discipline is concerned with the relationship between chemistry and biology? Nor does it help decide which comes first or which one explains another? Until very recently it would have been argued that such inquiries are not science, but belong to the philosophy of science. This is becoming less and less the case. The preceding figures are not the results of the management sciences nor organizational theory, but state experimental findings. Bohr's admonition is not a mere comment about physics, it is a physcial claim. In a similar manner, medical informatics does not consist of comments and assertions about medical knowledge, its content is a part of medicine.

The things which we teach to medical students are conveyed through the use of descriptions couched in ordinary language. And these descriptions have systematic properties which are important to understand. First, as Figure 3 shows, these hierarchical descriptions correspond to different scientific undertakings. They are characterized by each having a vocabulary which is appropriate for the descriptions needed in the particular field. The individual terms in these vocabularies have sharp and precise meanings at the lower hierarchical levels, and they become fuzzy and ambiguous at the top. This gives rise to the lower level sciences being referred to as "hard sciences" and the upper level ones as "soft sciences." For example, the notion of electric charge — a low level property — is a sharp, precise and unambiguous concept. In contrast, the high level attribute "consciousness" includes a variety of states which may differ slightly from one another so that a useful term must span a number of specific instances.

A second characteristic is that these low level predicates are also *necessary* to the definition of things (every atom has an atomic weight), but as we ascend the hierarchical scale, the clinical attributes of diseases tend to become *contingent* (not every heart attack patient has chest pain). Finally, we note that the "basic sciences" are primarily horizontal undertakings and their activities lie along a given level. Chemists work on chemical problems, and their answers and discoveries become a part of chemistry. Medicine, in contrast, is concerned with vertical relationships and with interactions between levels up and down the entire hierarchy.

Figure 4. Hierarchical Levels of Medical Descriptions.

Level-0	Patient as a whole
Level-1	Major patient part: e.g., chest, abdomen, head
Level-2	Physiologic system: e.g., cardiovascular system, respiratory system
Level-3	System part, or organ: e.g., heart, major vessels, lungs
Level-4	Organ part, or tissue: e.g., myocardium, bone marrow
Level-5	Cell: e.g., epithelial cell, fibroblast, lymphocyte
Level-6	Cell part: e.g., cell membrane, organelles, nucleus
Level-7	Macromolecule: e.g., enzyme, structural protein, nucleic acid
Level-8	Micromolecule: e.g., glucose, ascorbic acid
Level-9	Atoms or ions: e.g., sodium iron

And when we attempt to describe diseases and their causality, the hierarchical description becomes essential. (Figure 5)

Figure 5. Attribute Network for Pheochromocytoma.

Level-0	nervousness, tremulousness
Level-1	headache, dizziness
Level-2	hypertension, polydipsia, polyuria, blurred vision
Level-3	nausea, vomiting, dyspnea
Level-4	dilated pupils
Level-5	cells large, irregular, or polyhedral; granular cytoplasm
Level-6	
Level-7	
Level-8	increased epinephrine, norepinephrine, VMA, metanephrine
Level-9	

In order to sort out the details of medicine, we need to indicate *explicitly* that patients can have (experience) "pain," and that molecules or membranes cannot. The latter, however, can undergo ionization or exhibit electric dipole layers, which patients are unable to. Likewise, the notions of etiology or pathogenesis can mean little unless we can explicitly point to causal chains (or segments of them) and show how an erroneous DNA sequence codes a faulty protein, which then fails to produce some needed enzyme, which allows some unwanted material to accumulate in an organ, which etc. And if such downward explanations (and upward causality) delight the reductionist in all of us, the downward causality ("stress produces peptic ulcers") which is equally plain to see, also needs explaining.

Now I am in no way proposing that these particular structural properties of information are the things which we must first introduce to medical students. As a practical matter, it will be necessary over the short term to introduce them to such things as floppy discs and operating systems. But as incoming medical students become increasingly familiar with computers (many already are fairly sophisticated), they will insist on a far more substantial fare. What I am suggesting, therefore, is that an understanding of these and other structural properties of medical information are an essential part of the general cognitive framework needed to understand medicine itself.

We go to considerable efforts to point out to students that patients' fears, perceptions, beliefs, and behavior *do* make a difference in their care. So also does the fact that patients cannot experience a low blood sugar although they may complain that they are weak or dizzy. A better understanding of the nature of medical descriptions helps us make these kinds of explanations more clearly and with greater force. The continuing study of these information structures and processes which form the special subject matter of medical informatics would appear to be essential for the emergence of anything which could resemble a theory of medicine.

Use of Networks for Medical Informatics Research and Training

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Since 1973, we have been developing the SUMEX Research Resource at Stanford. SUMEX comprises a national community of groups researching artificial intelligence (AI) in medicine. In addition, Standard-based AI in medicine projects and our medical computing training program take advantage of the evolving computing environment at Stanford.

Part of our task has been to implement an extensive network, and the lessons from our experience are generally applicable to any project that requires linking multiple centers that have different communication and computation needs. There are two generally applicable lessons which we've learned:

1. Research and applications networks must continually expand as new tasks are taken on,
2. Network environments affect the way in which research projects are planned and carried out.

We will exemplify these two ideas by describing the SUMEX network and its evolution over time.

The SUMEX Network

The SUMEX resource, sponsored by the Division of Research Resources at the National Institutes of Health, has the primary mission of promoting research in AI applied to medicine and biology. The resource provides computing facilities for existing and pilot projects. Software developed at the resource, such as the E-MYCIN expert system shell, are made available to member projects. In addition, advice on the design of local computing environments is made available. SUMEX has both a national and a local community. Local projects include the ONCOCIN program for cancer therapy advice. National projects include the INTERNIST/CADUCEUS project for diagnosis across the range of internal medicine diseases.

Over the past fifteen years, the configuration of the SUMEX resource has changed dramatically while the mission has stayed the same. It has evolved from a single general-purpose computer with nationwide access through terminals into a diverse collection of specialized machines connected via a range of communication networks. We started with a large research timesharing system called SUMEX-AIM, a Digital Equipment Corporation (DEC) DECsystem-10 (later upgraded to a DEC-2060), connected to the TYMNET and faster ARPANET national networks. Using local telephone access, these networks provide a communication route between cities across the country and various computers, including SUMEX-AIM. People working locally also could call the central computer directly. As demand on the system increased, we expanded the central computer resource. As the research projects matured, we developed a need to test the programs in an environment that was not hindered by the unpredictability of a timeshared computer. A DEC-2020 minicomputer, which ran the same programs as the larger SUMEX-AIM system, was made available for the evaluation of programs and for demonstrations. The DEC-2020 became our first model for what is now known as decentralized computing. Although it provided an excellent test-bed for experimentation, it raised many new questions regarding networked computers, such as: How fast must connections between computers be? If I make a change in a program on one computer, how will that change be reflected on the other computers? Where will the programs and data be stored?

In the early 1980s we realized that instead of many people trying to timeshare one large computer, they could work more effectively using powerful interconnected workstations. We built a network of workstations using the Xerox 1100 family of Lisp machines designed specifically for the type of computation needed for decision-making systems. Although these machines are powerful on their own, their functionality is increased by networking them together with large-capacity file servers and other network services (such as print servers to output the results of the computations). Thus, the resolution to the problem of program management on several machines was to create central file storage where all information could be stored and which could be accessed very rapidly by individual machines. Information could be gathered at the beginning of the session by the workstation and put back at the end of the computation. The network communication paths support multiple connections at speeds on the order of millions of bits per second (the most recent dial-in modems are 2400 bits/second).

As the programs became larger, the amount of necessary storage increased dramatically. Although the central SUMEX-AIM computer can act as a network device for program storage, known as a *fileserver,* it has become necessary to dedicate special machines for this task in order to obtain greater speed and storage capacity. Thus, as systems become decentralized, network demands increase and new kinds of central resources may be required. The standards for communication across networks also have been changing in recent years. Both the hardware configuration and the languages used to send information, called *protocols,* have evolved. We adopted one of the prototype networks for connecting computers, but recent commercial versions provide greater bandwidths.

To connect two similar or dissimilar networks, another specialized computer, called a *gateway,* is used to facilitate the communication. Stanford's evolving network is built of a number of subnetworks connected by gateways. Because of the limitations of distance and speed in most current local-area network designs, an amplifying device known as a *repeater* may connect the subnetworks together. Stanford's network evolved as a grass-roots effort; interconnecting subnetworks were established as the various groups needed to communicate electronically.

Remote Use of SUMEX

The projects not located at Stanford that use SUMEX are known as the *national community.* INTERNIST, the medical diagnosis program which was developed at the University of Pittsburgh, demonstrates how a project that is physically remote can take advantage of a national computing resource. Initially, all the computing was carried out on the DEC mainframe computers over the TYMNET network. This arrangement was advantageous because the three-hour time-zone difference meant that researchers in Pittsburgh could use the system before the people in California began their work, causing time-sharing delays. An electronic mail facility allowed for communication among researchers independent of the time-zone differences. To increase the communication speed, the INTERNIST Project was connected to the ARPANET network. In addition, the INTERNIST Project acquired a DEX VAX minicomputer, which allowed some of the computing needs to be handled locally, although the development of the description of diseases continued on the national resource computer in California.

To explore a number of computer-intensive approaches to diagnosis, several Lisp machines were purchased for use in Pittsburgh. More recently, a version of INTERNIST was developed for use on a personal computer. Applying personal computers to specialized tasks in system development represents a substantial difference in size and expense compared to the first SUMEX computers. Although these machines are also located in Pittsburgh, the information stored on them can be transferred via the network to SUMEX-AIM for testing by other research groups around the country. This demonstrates the increased need for network communication as local computing facilities are developed.

Local Use of SUMEX

In contrast to INTERNIST's use of SUMEX is that of the PROTEAN Project. PROTEAN is a project to determine the three-dimensional structure of proteins given data from nuclear magnetic resonance (NMR) experiments. This system is rooted in the local network at Stanford. A DEC VAX-780 (a large minicomputer) is used to do the geometrical calculations which are necessary for the determination of three-dimensional coordinates. The results of these calculations are then displayed on a specialized color output device known as a SUN IRIS. Another DEC VAX computer, used as a fileserver, stores intermediate results in the reasoning trace of the program. A Xerox Dorado, a very-high-performance Lisp machine in the 1100 family, is used to do knowledge-based reasoning for the symbolic portions of the problem. Program development is accomplished on slower Lisp machines.

Conclusion

The acquisition of specialized machines for specific processing tasks is the trend in modern biomedical applications of computers. In order to make these machines work effectively together, research projects must be planned with reliable high-speed communication networks as part of the system design. The networking environment must be able to be extended, upgraded, or rearranged as the research progresses.

Medical Education and Development of Medical Informatics at McMaster University Faculty of Health Sciences, Hamilton, Ontario, Canada

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The Educational Milieu at McMaster

From one perspective, the approach to health sciences education at McMaster can be viewed as an experiment which, although it has already borne fruit, will bear its finest crops during the "Information Age" due to the improvements in information management made possible by new technology.

The process of education at McMaster[1] is problem-based "learning by inquiry." From the first day of school, students are given health care problems to solve and they do so by developing the skills to extract pertinent facts from a wide range of information resources in the form of print materials, audiovisual media, the expertise of the faculty, and the students own experiences with real and simulated patients and health care situations. In this environment, self-directed learning skills are essential and critical appraisal of evidence is one of the most important tools for survival. This is a departure from traditional methods of education in the health sciences in that the students must discover what is important to know about the health problems they encounter, rather than having the faculty tell them what is important. The method is predicated on the principle that the knowledge base in health care is constantly changing and that students must therefore continue to learn for life if they are to avoid obsolescence beginning at the time of graduation.

This educational strategy demands that the student develop superb information processing skills and places at a premium any methods of information access that can refine and speed the process of learning. The computer has opened up new routes that promise to galvanize this learning process.

The Problems of Information Processing by Health Professionals

Optimum use of information technology requires an understanding of the problems that clinicians have in managing information. Studies at McMaster[2] and elsewhere[3] have shown that clinicians have difficulty in handling probabilities in clinical reasoning, in communicating with one another precisely[4], in keeping up with new medical knowledge[5], in answering questions in "real time" as they arise in the course of delivering medical care[6], and in applying recommended procedures when the situation calls for them[7]. Unfortunately, recognizing these problems is not as easy as dealing with them. I will describe some of our rudimentary efforts to come to grips with them.

The Use of Information Technology to Overcome Information Problems

1. Critical Appraisal of Medical Evidence and Online Literature Searching

During the last few years, we have been attempting to define and develop electronic means for improving the access of clinicians to information when and where it is needed. We have been basing our work on the premise that what is needed is not access to more information, so much, as faster access to better information. To illustrate this point, I will describe our work in the area of critical appraisal of health care evidence. Beginning in 1978, we began a series of courses, the purpose of which was to teach health professionals to apply a set of common sense and scientific principles in their reading of original studies published in the biomedical literature. The objectives of applying the principles are to discern, quickly and reliably, whether the studies are both applicable to the health care problems that the practitioner has to deal with and valid in the evidence they report. In a controlled trial conducted among clinical clerks in our medical program we found that these principles could be learned within the context of the usual learning environment of our school and that students became more discerning in their reading[8]. However, it soon became apparent to us that being able to apply the principles of critical appraisal did not mean that these principles were often applied when students were confronted with questions generated in the care of their patients on the wards and in the clinic. A major barrier to using this approach when it might really count is the time that it takes to find the best study ever published on the problem. Even with online literature searching readily available — during regular weekday hours — in our Health Sciences Library, the time gap between the ward and the library has proven too great for all but the most avid information seekers. This observation has led us to explore the possibilities of end-user online searching on hospital wards. We are not the pioneers in this field, of course, as several studies have already been published about electronic searching of the medical literature by clinicians[9-11]. However, we see our own contribution to the field being primarily in the area of evaluating the means of online searching, the effect of it on information access and, even more important, the effect of access on the knowledge and skills of clinicians and the health outcomes of their patients. This is a territory that is almost completely uncharted at present and we feel some urgency in documenting whatever benefits electronic literature searching by end-users may have before it becomes so widely available that evaluations will be

difficult or impossible. While I certainly would not advocate the slowing down of implementation of this or other electronic facilities, I am making a plea here for a much more substantial research effort in the immediate future so that we can understand and refine the use of such techniques in a timely fashion. Our own work to date has included the testing of some 14 permutations and combinations of access routes to the MEDLINE file[12] and, more recently, the ability of clinical end-users to retrieve relevant citations during personal online searching after a short course on searching, and in comparison with trained librarian searchers (unpublished data). We also consider ourselves fortunate to have been included as a beta test site for the new "Grateful Med" search software from the National Library of Medicine.

2. Calibration of "Subjective Probabilities" and Computer-Aided Quality Assurance

The difficulties that clinicians have with estimating the likelihood of the diagnosis, prognosis, and therapeutic responsiveness of their patients appears to be at least in part a matter of poor calibration. This is, although objective evidence is available concerning the information content of specific aspects of the patient's presentation or diagnostic test results, the clinician is not knowledgeable about this information or too inexperienced to tailor the information he or she has to the specific patient. This is despite the fact that, in the process of caring for patients, we generate a great deal of information that could be used to test and refine our accuracy. For example, each time we see a patient we formulate an initial diagnosis within moments[13], then order diagnostic tests to confirm or rule out the diagnostic possibilities. However, we do not keep track of how often we are right or wrong and thus fail to take advantage of the almost immediate opportunities at hand for rating and improving our performance. Of course, some elementary bookkeeping would be required for us to check on our performance in a systematic fashion and this bookkeeping is both time consuming and tedious. Thus, although we might see hundreds of patients in the course of our education, we do not keep records of the frequency with which our initial predications of their diagnosis and the results of tests we have ordered for them are within reasonable limits of accuracy. To wit, none of us can say with any degree of precision or assurance just how accurate we are.

Computers, of course, are very good at bookkeeping but someone has to enter the data for them to perform this task. The challenge here is to place the computer in a strategic location in the flow of care so that data entry serves two purposes, one that is immediately rewarding for the clinician and another that does the bookkeeping. With this in mind, we have been developing a computer order-entry system that will allow the physician to enter all diagnostic and treatment orders for ward patients efficiently, producing a typed copy for the chart (we are not up to a paperless chart system now or in the foreseeable future) in return for having the orderer identify the diagnosis that is being considered, the likelihood of this diagnosis and, for each diagnostic test that is ordered, the likelihood that the result will be abnormal. These initial predictions can then be compared with the test results as they return — automatically as part of the hospital information system when this facility eventually exists in our institution. With the preliminary off-ward testing that we have done with the order-entry system, we have been able to show differences in performance for different levels of training with only a few patients per student at the clerk and resident level (unpublished data). Once norms are established for various levels of training and for the ordering of specific laboratory tests, it is our intention to use this information to provide feedback to individual learners and to provide feedback to diagnostic test services concerning possible remediable sources of misunderstanding of the tests they offer.

The educational principle that the computer is potentially allowing us to exploit here is a powerful one: audit of performance with corrective feedback. Audit and feedback techniques have been shown to improve practitioner performance in several studies of quality assurance and continuing medical education[14]. The difficulties with this method include the expense of obtaining the audit, generally requiring trained staff and thus high salary costs, and the delay in making audit results available for feedback, this delay being one of the important negative determinants of the impact of the intervention. If the auditing can be done online as part of a hospital or clinic information system, and the results can be made available concurrently, then one would predict a much more potent effect on performance.

3. Personal Filing Systems.

Health care students and practitioners accumulate copious quantities of materials that they have encountered in the course of their learning and attempts to keep up to date. These materials are a microcosm of the medical literature: they include documents that are not useful or are outdated but also information that would be useful if it could be retrieved when needed again. Unfortunately, most of us lack the library skills or

motivation and time that are required to keep our collections in an orderly and weed free fashion. In the hope that order can be brought to this process, we have prepared a workbook that guides users through the key decisions that they must make to create a functioning personal filing system. To disseminate the necessary skills, we hold annual half-day workshops for entering classes of students, strategically timed just before their first Christmas in the program, when they have acquired enough material to be concerned about how they will ever relocate it when they need it and when they have some time off to start their own system. Until recently, our approach has been a manual one, with a variety of options to suit the study habits and energies of the students. However, with each succeeding class over the last three years, increasing numbers of students have had their own personal computers and there has been increasing spontaneous demand for instruction in creating computer filing systems. To assist students who want to computerize their files, we have reviewed some of the burgeoning numbers of commercial and homegrown filing software programs that are now available and have created sample files on one of these systems, while demonstrating the use of a larger system that we use for our own reprint collections on a super-microcomputer system. As the capacity of microcomputers increases and in anticipation of the day when all students will have their own computer, we are preparing for providing all students with purpose-built software for personal filing.

4. Expert Systems.

A fourth area of our current interests is that of expert systems or artificial intelligence. In one application, we have been collaborating with a physician in Texas who has developed user seductive software for the critical appraisal medical literature, based on an introductory textbook on clinical epidemiology[15]. The microcomputer program, named LITEVAL, guides the user through an algorithm that covers the key features of methodology and, most important, calculates key summary statistics such as the confidence intervals around differences between treatment and control groups and the sensitivity, specificity and predictive value of diagnostic tests. The output is a summary sheet that can be attached to the articles being reviewed, a useful aid-memoir and method of facilitating discussions at journal clubs and clinical teaching rounds.

We have also begun to struggle with how one can vet the vast amount of ''expert'' and artificial intelligence software that is being produced. Most of this software comes with glowing claims from its producer but little or nothing in the way of evaluation beyond the occasional testimonial. We are now in the process of setting up a review system in our Faculty for software, with panels including a content expert, and educational expert and a student end-user. It is our intention that programs that survive this first stage of review will go on to more formal evaluation, but we have not decided on the precise mechanisms for this process. We have also recently acquired enough microcomputer equipment in our library and Computer Services Unit to provide students with the means to use the software we are acquiring. Parenthetically, it is worth mentioning here that we are specifically not offering students courses in "computer literacy." Rather, we are in the process of defining and developing an increasing number of computer applications for students and practitioners that they will find indispensible in the execution of their clinical activities and continuing learning. A next step will be to make the software available in the clinical settings where it can be most useful, but we are not ready to do this at present.

5. Computer-aided Learning.

A related area of our current endeavors, and the least developed at present, is that of making available to students the rapidly growing quantities of instructional software. Our school entered these somewhat treacherous waters at a time that was likely too early. Some highly sophisticated mainframe computer models of physiological systems of the body were produced[16,17], affectionately and perhaps somewhat narcissistically named MacMan, MacPuf, MacPee and MacDope. These models were not prepared in a particularly ''user friendly'' mode and were also not ''problem-based'' in the manner in which they interacted with users. As a result, both faculty and students ignored them for the most part and perhaps rightly so. We are now in the process of civilizing the models, making them available on microcomputer and attempting to integrate them into the curriculum as resources for relevant health care problem exercises. We are also developing a computer-based approach to presenting health care problems, to provide students with a means of instant feeback and self-assessment.

Beyond this local effort, we are just now setting up the mechanism by which we can review and assess the commercial products that are available along with the ''expert systems'' that I mentioned a moment ago. One

approach that we have considered is simply to make educational programs available through the library and have consumers vote with their keyboards on their usefulness. We have rejected this approach because we believe that our acquisitions must fit in with the principles of our educational philosophy of problem-based learning as well as having factually accurate content. Thus, we feel obliged to set standards for content and modus operandi and to set up a review mechanism that will apply these standards systematically. This will be a large and continuing task that will take broad faculty commitment and participation. To initiate this process, we have just completed a survey of our faculty members to determine who has the expertise and desire to become involved in the venture.

6. Educational Planning.

One of the most important legacies of the founding fathers of our institution is an organizational structure that has become known as matrix management. In this approach, department chairmen function as human resource managers. Programs, such as the undergraduate medical program, draw resources from whatever departments (medicine, surgery, and the like) they are required. This permits central planning around educational themes, avoidance of turf wars (since none of the departments of clinical disciplines "owns" a block of the curriculum), and relatively rapid and painless integration of changes into the programs, as long as these changes are well conceived.

The quality of the conception of new curricular elements depends on the educational expertise of the faculty members who serve as planners and this is in no small way dependent on the quality of the information they have available to them. Quick and easy access to information is particularly important in our system because planners tend to serve for only a few years in any one position and poor information access often means "reinvention of the wheel" by successive planners. With the assistance of a grant from the Macy Foundation, we have developed a computer database to provide educational planners in the MD program with accurate information concerning what is in the curriculum and how specific problems are used and perceived by students and faculty. The database contains information on all the health care problems used in the curriculum, along with their key biological, population and critical appraisal concepts; their clinical and basic science content; resources recommended and available for them; and evaluations given them by students. The database is used to provide planners and discipline coordinators with feedback to help them modify problems for future use. It is also valuable for avoiding duplication of problems across units of the program. It can also be used by students and/or tutors to locate problems that illustrate specific issues and principles.

Conclusions

We are attempting to move on several fronts simultaneously and feel that we are making some progress, but with the constant feeling that we are falling further and further behind. We look with envy at the institutions who have much larger capital and personnel investments in electronic information processing but feel that there are some advantages to not having the wherewithal to computerize our environment more fully at present. First, we are concerned about the lack of formal evaluation of almost all computer applications in health care at present and, with our in-house capabilities for evaluation, feel that we can make a contribution by assessing individual applications before they become so widely disseminated in our environment that evaluation becomes problematic. We are very mindful of this latter problem which unfortunately pervades the whole field of technology. Second, we are determined to avoid having computer technology and software drive our educational programs rather than using the principles on which our curriculum is built to help us define and develop computer applications that aid us to achieve our objectives. Third, by observing closely the pioneering work of the institutions that are represented here today, we hope to be able to learn enough to steer clear of perils and capitalize on the advances that you create. I would therefore like to end my presentation by thanking the organizers for the opportunity to participate in this important and illuminating event.

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Questions and Discussion

Question

Thomas L. Lincoln
Arthur Anderson & Company
(University of Southern California)
This really is a question about communication directed to the whole panel. Dr. Reynolds mentioned Romans and the roads, and Dr. Gorry treated us to "Med-Wars." Then, Dr. Lorenzi pointed out all is not easy when you try to introduce communication. I am reminded that when the Romans built roads to the barbarians, the barbarians marched down the roads and sacked their cities. There are a lot of people who are seriously worried about that. In fact, it is even more complicated by the new issue of patenting academic research, and there are already a lot of arguments as to who they belong to and what will happen there. Clearly, this is an attempt at communication and an extension of communication which meets all kinds of resistance. I would like to hear from some of the other speakers besides Dr. Lorenzi, who mentioned it already, what their experience has been.

The question essentially concerns, as you say, the idea of an "extended notebook." This allows a lot of access to information and squabbles and arguments about whose information, priorities...all kinds of things. It is not evident that everybody favors either teamwork or information exchange. The way that's introduced becomes quite complex in detail.

Answer

G. Anthony Gorry
I think it is evident that everyone does not favor cooperation and information exchange. The point is, however, in respect to our particular project, we are very concerned about confidentiality of information. One of the things we are going to have to look at very carefully is if one allows the sharing of information, even within a research group, how can one control it? Such simple questions as: can one go back and erase information? This is a very difficult problem for us to understand in the abstract, and it will be equally difficult when we come to a specific realization of it. Our particular approach is to sign up a few research groups who actively want to use this technology, and it is our hope that we will demonstrate its superiority. If it doesn't sell itself, in some sense, in the context of being used by very effective research groups, then it will not succeed. We did the same thing with our technology transfer company. We did not say everybody has to use it. We said we will strike better deals or be more effective and you will come to us — those of you who are dubious. I think we are going to follow the same approach in our particular environment in our IAIMS project. Now, whether we will be successful, I don't know, but there are a lot of people who really want no part of even being on our network. It is an odd thing to me why one would not want access to a network, but there are people who believe that. So I think you have hit on an important point. We can't do "top down" planning at Baylor.

Robert E. Reynolds
Our system also will be optional from the standpoint of the researcher to make use of the Ethernet or the PBX per data exchange, data transfer, and it will be up to that particular researcher to identify with whom he is willing to exchange information. I'm not that technically proficient to tell you how that happens, but my colleague, Dr. Johannes, says it is reasonably easy to do. On the hospital side, they have a different problem, that is, patient data confidentiality. On the one hand, we have the malpractice lawyer saying, "Don't let anybody have the data but the exact doctor, house staff and nurses." On the other hand, you have the house staff, nurses and doctors saying it's an open book on the rack on the ward anyway, anybody can walk up, so why do you try to lock people out of the information data base on patients? We are still struggling with that on the internal side of Hopkins Hospital, and I'm not sure where we will come out, but probably limited access by code.

Robert A. Greenes
This is another issue, I think, in looking at sources of knowledge or information that can be provided, whether it be a decision support analytic tool or a knowledge base bibliographic search service or something like that; that is, even if one can achieve some willingness to share these kinds of capabilities and can develop the wires that connect them together, one is faced with an inconsistent interface among them and no real integration, let's say, of the decision support tool and the data base which may exist on different machines physically. So the alternatives one faces are those of having to develop new kinds of front-end environments, like an electronic notebook or something like that, which somehow translates the output of those various systems or re-implementing all of them on a central system. I think these are difficult choices that involve both cooperation and trade-offs in terms of deciding what is the best way to achieve that.

Question

Kent Stitzer
University of Puerto Rico
The question is actually directed toward the whole panel, but specifically to Gerry Hendrickson and Octo Barnett. How do you allow more faculty release time to carry out the IAIMS programs than normally is allowed within a usual institution for any kind of computer work by faculty?

Answer

G. Octo Barnett
One of the nice advantages of keeping a very focused tunnel vision is to really not be willing to answer questions like that. I think the dean has a major problem. I think medical education has a major problem because I don't think we have structured how, indeed, we are going to reimburse for medical education. The research issue is a little bit better because that is supposed to be self-sustaining in its own right. However, it is not at all clear what is going to happen where the "problem" of physiology gets $800,000 a year, but there is no physiology course. I don't quite know what is going to happen, but I'm going to stay out of the firing line.

Gerry Hendrickson
I had the same sorts of things to say. As you know, the incentives against the faculty spending a lot of time and energy on education are great. We have no plan to allow faculty more release time. It is not clear whether we would be doing them any favors if we did allow them more release time. What we are planning to do is bring in individuals who can work with faculty and do some of the "leg work," who will work with faculty that have ideas about how they want to introduce computers into their courses, and thus relieve that faculty from having to do some of the work.

Question

Philip Lief
Albert Einstein College of Medicine
No matter what we say about medical students, most of them graduate and move on to another institution. How dependent will we make our students on a particular system and type of education or information gathering, and how well or poorly will we prepare them to move to new institutions and to new places with different, if not more limited or more extensive, systems? It concerns me when I hear about the differences in the programs that are being developed.

Answer

G. Octo Barnett
We get asked that question fairly frequently. I don't find that a particular issue of concern, partly because technology moves so fast and the small likelihood of still using the same technology that they had as freshmen. We're probably going to focus most of our efforts on the clinical tool assistance activities. These will be self-standing on their own systems that they can basically take with them. My perception is that four years from now pretty much every intern and resident will have his own system and some way of carrying it. The way that this field is moving, I think, the question is not going to be whether we are going to control it or worry about it because it's happening. I think what we need to do is try to develop software that has as easy a migration path as possible to a variety of systems. That's not going to be easy, but that's really what we should be trying to do.

Robert A. Greenes
I think another aspect that should be considered is that, as a lot of these prototype projects are going on at Harvard and elsewhere, we are really finding out what works, and that is what is taking 90% or 99% of the effort. I think once something is identified as "working," the re-implementation of it in another environment that may be more portable is a lot easier than the first time around. An example, I think, is the INTERNIST I Implementation which is now a personal computer. A lot of that capability which really required a DEC 20 to develop initially is beginning to get to the point where it can be on your own personal workstation.

Marsden S. Blois, Jr.
The question of standards, I think, Octo has answered. The systems are all going to be different. They are going to be changing anyway. The important thing is to give the students the hands-on experience with a system that has a computer behind it, and then making the transition to another system is much easier than if you are starting from scratch. It is like automobiles in the old days before they all decided where to put the clutch, the brake and everything else: once you learn to drive and learn to count on a car, then you can move to the next car and learn the details of that system.

Homer R. Warner
I was only going to say that I think that the role of the technology will be under the table. It won't be the technology that the student needs to learn. As the technology gets better, it will become less and less apparent to the student or the physician or whoever. It is the medical content that we need to get them used to using and accessing, and the notion of the concepts for accessing information. That technology is different today than it was last year, and it will be different next year. As it gets better, it becomes less and less apparent to the student. I think what is much more important is to standardize the nomenclature.

Nancy M. Lorenzi
I'd like to just briefly support what Dr. Warner is saying: really, what we were talking about this morning is information literacy. It is teaching those life-long learning skills rather than the technology; that's all going to be transparent. So, our task should be teaching the problem solving skills, teaching those areas not necessarily being bound in any particular technology.

Marjorie P. Wilson
I was just going to add that if you are fortunate enough to get people who have been at the cutting edge of such developments come into your institution and you haven't got it, then they will insist on the change happening around them and they become opinion leaders. I'd love to have a couple of them in a few years in our place.

Question
Alvin M. Berk
SUNY Health Science Center at Brooklyn
I'd like to direct this to Jay Binder particularly and then to the panel in general. Is there any sense that the acceptance of the kind of tools we have been talking about here, today, is different among those medical students whose career plans are directed towards being practitioners as opposed to those who seem to indicate an interest in an academic career?

Answer
A. Jay Binder
The only answer I could really give you is my perception that while there is some difference, it is not as great as we may think. Many medical students see computers as something that can make them more efficient and more effective, and in a better position whether they are going to academic medicine or going into clinical practice. I don't think that there is a great disparity in their interests or their motivation to learn more or to accept some of the things we have been talking about today.

August G. Swanson
I don't have the data directly in my head, but my memory says of those students who say their first option in their career would be academic medicine, about an average of 24 percent of the responding students, they think that their exposure to computers is even more inadequate than those who were planning careers other than academic careers.

Naomi C. Broering
Through IAIMS, what we are basically supporting are information techniques and information data bases, and the kind of thing that would address the needs of the typical physician and student in solving some of their clinical problems or their research problems. What we are trying to provide is something for the general medical student, not necessarily the one that is going to go into some special area or even medical informatics. It is a very early opportunity to give them some experience and then, I think, what will happen is that a few of those will then become interested in the field and specialize in medical informatics. I think that it is important for IAIMS to support the things that are broadly needed throughout the medical sector, without regard to possible student futures.

Majorie P. Wilson
I think that practicing physicians these days are becoming much more aware of quality assurance, risk assessment, and such things. These kinds of things are absolutely dependent on information systems, and I think that very shortly there is going to be a much greater reliance on having such information available. It will have a much greater degree of acceptance.

Question
Doris Bolef
Library of Rush University
We have talked a good deal about medical students and how we want to convert and change their perceptions, change the ways that they learn from the lecture method to the life-learning and other forms. However, they are in an environment where many of the faculty have learned how to teach in another way and in an entirely different style. Are there people who are thinking seriously about how to help these senior faculty people convert from methods with which they have been familiar and have

done a good job educating physicians for a good many years? I am concerned about this, and I can see where there is a problem in many institutions.

Answer

Naomi C. Broering

There is a lot happening to assist faculty. The special disciplines and their associations are sponsoring continuing medical education courses for a lot of the faculty, and they will attend them. I have found, more and more, that some of our faculty talk about special institutes they have attended. So they're not just sitting still, and waiting for the institution to do it all for them. There are some that are moving in that direction on their own. They go to their annual conferences, and they are exposed to new ideas. There is also peer pressure to keep up. Also, some of the associations are now addressing new teaching approaches, and I know from experience that the chairmen of pharmacology groups have changed their approach. They are no longer leaning towards asking the students to memorize 2,000 drugs. It's a slow process, but it is happening. At the institutions, through IAIMS, many of us talked about the fact that we are addressing training and instructional opportunities for them, and the faculty take advantage of these. We are also getting some of our products in the departments, and they'll start to use them. I don't know of anything very specific that is going to cause change quickly, but I think there are a lot of opportunities. I think everybody here at the table could probably talk about some of the special workshops, informatic days, that they have had at their institutions. This is what starts that sense of "Gee, we must catch up. We must do something."

G. Octo Barnett

I think you bring up a very valid point because one of the reasons why the lecture method has been so predominant is that it is very, very efficient from the faculty viewpoint. It is very simple for most of us to "have slides, will travel," and give a lecture fairy easily and very quickly on a certain number of topics. We've done it many, many times before. My impression is that, at least in our school, it is very hard to make any generalization about the faculty. It is a very diverse group of individuals. There are a large number of them that find that this type of educational, problem-oriented thinking to be very, very exciting. After all, after you have given the same lecture for five years, there is not a great deal of pay-off that you get from giving it. The problem of basic learning experiences is a very different type of issue. If you like to teach, the problem-solving learning experience is a lot more fun than giving a lecture, and it is a lot more rewarding. You have a certain amount of anxieties to overcome about not being an expert for all the questions. I think the hardest question is going to be an economic one. In the reimbursement system with one faculty member giving a lecture to 150 students, you could sort of divide up and look at what it is going to cost, but when you have problem-based learning where a faculty member is dealing with eight students, ten students or twelve students at a time, there may be a very different set of concerns. I think the faculty, probably a number of faculty, will need a certain amount of retraining. There are faculty workshops, and we have two members of the "New Pathway" staff who spend a lot of time and effort giving practice sessions, experiments, demonstrations of problem-based learning activity to the faculty. A lot of the faculty find this very exciting, even some of the most conservative ones, and have felt, "Gee, this is a lot more fun." I don't know how the economic issue will be resolved. I really don't know how you are going to try to "cost out" what medical education's costs are. That would worry me a lot more than the training activities.

A. Jay Binder

I think we need to remember that these same faculty people that you are talking about, like medical students, are adults. They have acquired most of their knowledge about the art and science of medicine through adult learning. I believe many of them don't realize that, but I think they have. I think that for us to try to lecture to them the glories of adult learning would be foolish, and we have to try to change their attitudes first so that they will be receptive to learning as an adult about adult learning and about medical informatics.

August G. Swanson

It wouldn't hold true for all schools, but for most schools I think the idea of having a lot of faculty stop teaching medical students probably would be a good thing. If there's any single complaint that we heard during the GPEP project, it was the complaint of the medical students that every faculty member wanted to only talk to them about his particular area, and the "parade of stars" is one of our great problems. So, I think there probably will be faculty members who cannot adapt to the new world, and that's fine; they can do other things. I am impressed with the idea that probably the average class of 100 medical students could be taught by a very much smaller number of faculty than are now involved.

G. Anthony Gorry
I am compelled to make one additional remark which I suppose is obvious: from my perspective, not being a medical educator, thus this is easy to say, it is less of an educational problem than it is an organizational change problem, and organizations are driven by perceived self-interests. Therefore, what will change faculties in some organizations is the perception that it is necessary for our long-term organizational success that we do change. It will have virtually nothing to do with the purported merits or advantages of doing things this way versus some other way. I'm sure that one could debate whether it is really worth investing another million dollars in molecular biology, but as long as it is perceived to be in the institution's best interest to make that investment, I think some of the concerns that Octo is talking about in justifying these expenditures will pass pretty easily. It is only when an organization perceives that this change has to take place that they start looking for the change agents, and they start making the kinds of decisions that have to be made. For example, we are pushing very hard in research, and you have heard illuminating statistics that our students at Baylor think we do nothing in education. That is because currently, and I think correctly perceived by the students, it has not been yet in our perceived institutional interest, what we would call critical success factors, to make that commitment. With decline in applicants and our concern about getting high quality students however, I already see the immergence of this as a high priority item for us. It is not so much an issue of, "Do we like this form of education, do we like that form of education?" From an institutional point-of-view, it is what do we need to survive?

Question

Kenneth R. Dirks
Texas A&M University
Our speakers today have eloquently made the case for incorporating medical informatics into the medical curriculum. I wonder how many of the institutions represented here have extended that to include in their prerequisites for admission, minimum course work in computer sciences or informatics?

Answer

August G. Swanson
To my knowledge, there are no formal requirements listed in any of the admission requirements so far.

G. Octo Barnett
I would be opposed to it. On the same basis, I don't think they should have calculus or organic chemistry.

Naomi C. Broering
I think if they had a degree in the computer sciences, they may want to stay with that because it is a very lucrative field.

Robert A. Greenes
Of course, it is probably obvious, most of the entering students now are increasingly computer-literate. I think, rather than calculus, though, I just as soon have them have background in probability and statistics.

Question

Ronald J. Pion
Hospital Satellite Network
I direct this to Dr. Swanson first, but not limit the response if there are others who are interested. What is the likelihood, if we could agree, that software drives hardware? There have been comments alluding to that. Certainly, the textbook industry hasn't waited for individual schools; they have seen this perceived need that Dr. Gorry described. What if AAMC elected to facilitate each member school to develop one software program. Is it possible that such a step by the AAMC, were it to come about, might create a lot of software in just a few years?

Answer

August G. Swanson
I'd like to think we're that potent. I don't know. This is a bit reminiscent of our experience with audiovisual materials. I always have hoped or assumed that, because of the higher level of power in the computer and information handling, we might not have that same experience that we have had with audiovisuals which is the "not invented here" syndrome. It is a terrible problem, and whether or not we can get any significant qualities out of just trying to stimulate each institution to develop something is, in my view, problematic at the present time. I'd be glad to hear about this from others.

Question

Ronald J. Pion
Hospital Satellite Network
I appreciate your answer Dr. Swanson and that was true, but is no longer true. Having on-line accessibility available for a beginning medical student, as long as that student knows where he or she can get such a better opportunity, the student will choose the better opportunity. The same thing will be true as satellite transmission grows. That's where I've gone because I couldn't stand fighting my colleagues any longer at a given institution. I'd just as soon make a ubiquitous satellite dish available, and have people use it. So, what I'm really asking is, "Can't we as adult learners look at what becomes universally available, and seek some of the best teachers, those who will enhance the learning of the student, and have them consider developing software?" Do we have to be stuck because the AAMC once had a bad experience with audiovisuals?

Answer

August G. Swanson
The audiovisual experience wasn't bad; it was illuminating. I do think what we are trying to do in stimulating the IAIMS program, such as the new report by the Advisory Committee on Medical Information Sciences, is going to be very useful because it is the best state-of-the art summary I've seen. I'm not sure at the present moment that I have enough conceptual ability to put together what I would consider the ideal stimulus developing system.

Octo Barnett
I might add one other thing: I think there is an underlying philosophy with which I agree that we really don't quite know what we would want to develop. I certainly don't think that the 150 medical schools are the same, and development would be almost a disaster in terms of planning because of the heterogeneity, the uneven quality, the different styles of interaction, the different hardware issues, and the different software issues. It is almost guaranteed to not be a very successful approach. I am on one of the planning panels here at the National Library of Medicine, and we are struggling with how one tries to facilitate the development and dissemination of computer based software. I think the only thing the panel has been able to come up with is a consensus that we provide more active support for knowledge about what's available, perhaps promotion of some lighthouse-type of activities to report new developments. We don't know enough, and the field is not ready to really standardize or engage in any sort of large bulk development. We still have much to learn, and I think the worst thing in the world to do is think "Gee, here is a disk, and here's a computer program. I'll just put in the disk, and somehow it works and makes my medical school better." That just doesn't work. The students may use it to a certain extent, but if you're really going to make a radical difference, it has to be done on a more fundamental scale then just making a software program available to a medical student.

Question

Logan Ludwig
Loyola University Medical Center
If the panel had a goal of asking us to raise more questions than answers, you have succeeded very well, at least in my case. I would like to ask about three concerns or areas that bother me at this time, not that there may be any particular answer available, but since you had more experience than I in this area, I'd like you to comment on either any one of them or all of them. The first is, that as a medical educator I must decide how much factual information is necessary for a student and, as a librarian, I'm still trying to decide how many books, journals, audiovisual materials, etc., I must have available to meet my needs. Now, under IAIMS, I am puzzled by how many nodes are necessary in the system in order to meet the needs of the institution.

Secondly, with the advent of miracle drugs, there tended to be some unrealistic expectations of the capabilities of medicine. The perceived capabilities of computers are also somewhat overestimated and may account for some of the confounding of the figures Dr. Swanson mentioned concerning IAIMS institutions versus non-IAIMS institutions. My question in that area is, "Are our expectations of what IAIMS as a management system can achieve for us really beyond its abilities?"

Thirdly, obviously, access to information costs money. Do our efforts to access all knowledge and make all knowledge accessible to everyone tend to artificially inflate the value of information and widen the gap between the "haves" and "have nots?"

Answer

Lawrence M. Fagan

I think the development of computer software, one example is expert systems, is definitely an area where the popular press implies that you can develop one of these things in three weeks or four weeks. A reasonable-sized project, like the one we are doing at Stanford in cancer therapy, has taken us six years, including switching the hardware technology several times. That's a much bigger problem than the kind of system that might be directly useful or needed by the students. The people here who have developed these programs over the years realize that the leadtime for producing software packages and testing them to the point where you feel comfortable having a student use it or integrate it into a clinical setting is a long period of time. I do not want to give the impression that these things can be produced very quickly. There is a problem right now in our area, particularly with expert systems, where the impression is very much out of phase with what the amount of effort really takes. I saw a *Business Week* article about developing two expert systems over a weekend, and I know that that kind of thing is not practical. You can prototype a little piece of a system, and some of these in expanded form might be appropriate for very limited student teaching, but you want even the teaching programs to have the same kind of flexibility and breath of knowledge that we are hoping to have for the programs that are actually doing diagnoses and therapy on the wards. We don't want it to be too limited.

Nancy M. Lorenzi

We heard from some of our colleagues today about the different management theories that exist. There's a fellow whose name is Philip Crosby, and he has a book called, *Quality Is Free.* He said that if we are going to establish a program, let's say on quality assurance and we put it in today, 1986, the time it will take to be fully accepted in any institution, whether at Cincinnati, Harvard, Utah or wherever, will be at least four years. It will be eight years before the change is complete and the new program is part of the "ritual." So, you have the view the IAIMS process as a change agent, and some of what we are talking about is going to take time. It is like throwing a pebble into a pond: the ripple movement takes time. Many of us are acting as change agents, and we're at the beginning of our change agent process. By the time you see an operational IAIMS, some of the concepts we're talking about, first expectations will have changed and evolved. IAIMS is really a concept that is looking at introducing change into complex organizations, and medical centers are complex organizations. Some of us are focusing on research, some on education, but the basic management philosophy is to foster an environment of constructive change. In this sense, IAIMS is not a matter of models or expectations.

G. Anthony Gorry

I want to comment briefly about the notion that we're adding to the cost of information. I think that is true to some degree. I think that, properly constructed, information technology can, in fact, be resource creating. I think the dilemma for institutions will be, "Is it wiser to wait and let someone else pay the admittedly high cost of getting into this business, and then try to absorb what they have discovered," or is it too risky to do that? In a constricting kind of economy or environment, it's very dangerous to assume that, when the other institutions have it, you will pick it up, and thereby catch up with them. This is a real organizational dilemma. I think, in fact, that the institutions that pay the price now, will come out some number of years from now substantially improved and in a much better competitive position. Some, presumably, will not. I think just the investment is sufficient. Initially it is very costly to do this kind of development, and if anyone tried to realize some of the scenarios that were presented today in full detail...we have a picture we show at Baylor of programmers in front of a furnace shoveling money into it. That's the kind of situation that we would be facing.

Homer R. Warner

I'd like to address your third question about the value of information: what kind of commodity that's going to be in the future, whether we're going to make it easier or harder to get, whether it's going to be more expensive, and what impact it's going to have on institutions. My own bias is that we are going to see information become a very important commodity. The information in Expert systems, for example, and the special data bases that represent the work of experts who filter the literature to generate summary information, are going now to textbooks as a very important commodity. Such systems and databases are going to be sufficiently useful and sufficiently general that they can be distributed widely. Unless we come up with some big changes in our reward systems in the academic community, the financial reward is going to become an important one. Just as was mentioned about the institution trying to survive by staying ahead of the game, I think one of the elements of survival is ways to distribute the expertise that we have in these academic institutions. You know that's really what we have, and we

distribute it now by cramming that expertise in the form of facts into medical students' heads, and hope they'll go out and use it. That's our product now, but another product is to get that expert or that group of experts to develop a restructuring of that expertise in a form that can be widely used by phsicians or other health care providers or even the general public. That's also a product. What we've become good at is in these other ways to structure knowledge, and to develop tools that can make information useful for quality control, for more efficient practice by "for profit" institutions. The whole structure is changing, and I would not be at all surprised to see information distribution become an issue unless we can solve this motivation problem. Right now, we are motivated to publish, but there are a lot of other ways to serve the information needs of the community than just publishing. I don't know how it is all going to evolve, but it is certainly one issue that we have to take into consideration in our planning.

Marsden S. Blois, Jr.
I think the marketing just mentioned, how these systems all come out, raises interesting points. One thing is that the creation and production of information and knowledge is not part of a zero sum game. You can keep creating. It is not like the quantity of gold that is in existence and this determines the price. So the economics are a little unpredictable, and it's like writing textbooks on plain geometry: people keep writing them. The rules and axioms and theorems are all the same, and the one that's the best tool wins the game. The economics of information are quite interesting.

Homer R. Warner
But the end product is a bit different; it is the delivery of health care. Only as far as that knowledge impacts that end product is the public much interested. They don't have the same intellectual interest in developing the systems that we do.

G. Anthony Gorry
I want to go back to the point of institutional investment and return, and sketch what may be a totally unacceptable and impolite scenario. Let's take the commercial world as an example. American Airlines for years invested an enormous amount of money in an airline reservation system. At the time that expenditure was being made, a number of people said that it was just a minor matter of efficiency for them. Similarly, United Airlines made a substantial commitment. If you look at the profitability of airlines and you look at the return on that investment, it was very, very substantial because United and American do not give away that service free. Similarly and it may be too dramatic, it seems to me that medical centers could find themselves in competitive situations where they will no long give away information resources. That they will hoard them and use them for competitive advantage. They certainly don't give away biology and its results as freely anymore since it has commercial value. I think the kinds of things Homer is talking about, where you have enormous investments of effort to build these kinds of systems, the presumption by other institutions that they will be freely given away, such as calling your friend at XYZ Institute and he will send you his IAIMS system, may be quite incorrect. You may find that even if you could accept it and use it, he may not be able to return your calls.

Robert A. Greenes
I want to mention one other change that is occurring concurrently with our effort and involvement with IAIMS, and that is in the publishing industry, embracing all forms of electronic dissemination of information. I don't mean just on-line networks now, but electronic software publishing, production of knowledge bases that are on CD ROMs, like the compact audio discs are now crammed full of encyclopedias and all kinds of knowledge bases, that one can begin to obtain for your personal computer. This will also change the economics, I think, of how people can and will disseminate their expertise. I am sure we will see shortly CD video mixed with the digital data and the audio data, and I think we are beginning to see a whole different kind of dissemination process emerge. There may be economics associated with these processes that will provide other reward systems for people.

Naomi C. Broering
I feel very strongly that, when we are given opportunities by the Federal Government to develop some programs, it is very important to share some of the things we do with others. I'm not saying that we have to share it freely, because a lot of "blood, sweat, tears, and time" goes into the work, but I do feel, as the schools get more experience with IAIMS, there will be some products that we can certainly share, things that we design, I would hope it is something that many of us around the table would be willing to do. As far as whether or not other schools should get into this game of information science, I don't think any of us can afford not to.

Closing Remarks

Donald A.B. Lindberg, M.D.
Director
The National Library of Medicine

I would like to thank the participants, both the presenters and those in the audience. I have learned a great deal from the session.

In trying to summarize why are we talking about so many different things at once, I think the following distinction helps to sort out some of it, at least for me.

We started to talk about education. There is a distinction between training and education. It isn't absolute and, in any particular lecture or lab session, I guess we can't always say exactly which one we're doing. Yet there is a difference. If we teach a medical student to run a hemocytometer, which I used to do, we don't say we are teaching hematology. Or, if we teach the student how to run a sphygmomanometer, we don't say that's equivalent to cardiovascular physiology.

An example that I've never forgotten, was immunology, which I studied with Elvin Kabat. His small book on experimental immunochemistry was published in 1948. A large part of it was about experimental methods. That was about all there was in the world worth knowing about immunology in 1948. Essentially, it said that Michael Heidelberger, David Nachmunson and Manfred Mayer had figured out how to distinguish between antigens and antibodies, how to quantify antigen-antibody reactions, by learning the fixed average percentage of nitrogen therein. It was possible to actually demonstrate the phenomena. The point I'm trying to make is that somehow, in spite of myself, I got an education in immunology. The reason I think so is that I can continue to follow that field which has grown many orders of magnitude greater and more important and more powerful in the intervening years. I am grateful to those teachers who gave me the beginning of an education in immunology, rather than just training in performing quantitative reactions. We must do so in this field of medical computer science/medical informatics as well. The training, the exposure, the access, and all the other aides are great, but we are really in the business of education.

We have to provide a level of understanding that lets our graduates of the health science professions go on for the rest of their lives learning about this field as it changes before their eyes, rather than just train them to turn the switch on "the network."

In any event, that's just one small aspect of the many things you all covered so very well. In parting, I thank you very much.

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